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Vegetated Filter Strip System

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Vegetated Filter Strip System

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Editor

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1 Introduction and Background

1.1 Purpose of Manual

This manual has been developed to:

- illustrate and describe the key components of a farm-based Vegetated Filter Strip (VFS) system
- allow farm owners/operators and other rural landowners the opportunity to carry out a preliminary assessment of the applicability of a VFS system (for their specific farmstead)
- outline the detailed design process for the development of a VFS system for managing agricultural runoff

This manual also provides case studies that show common design scenarios.

In Section 1, the manual provides information that defines the purpose and function of a VFS system and its primary components, outlines, and permitted applications. It also discusses the regulatory framework surrounding the development of VFS systems.

Section 2 describes each of the VFS system components and outlines the design considerations associated with each component.

Section 3 outlines the detailed engineering criteria and methodology for the design of a VFS system by a qualified professional. This section explores the use of VFS systems, outlines design guidelines that can be followed by the user to lay out a farm-based VFS system, and provides design calculations to determine the details of the VFS system.

Section 4 includes a Design Guide, which provides a step-by-step process for working through the design of a VFS system.

Section 5 provides case studies of two VFS systems, along with detailed design calculations.

Supporting documentation related to the design and implementation of a VFS system is included in Section 6, Design Tables. Table 6.1 gives the maximum runoff storage/settling volume for various centres in Ontario using the conservative method. Table 6.2 gives the minimum storage/settling volume required and peak discharge rate using the rational method. Table 6.3 gives the area required for an infiltration area based on saturated hydraulic conductivity of soil texture classes and discharge flow rates.

A Glossary is included in Appendix A at the end of the manual.

1.2 Purpose of VFS System

The purpose of the VFS system is to treat agricultural runoff (impacted by animal manure) by reducing loading of nutrients, organic matter, pathogens and other associated contaminants.

1.3 Application of VFS Systems

The VFS treatment technology applies to:

- the treatment of runoff from outdoor livestock yards or outdoor confinement areas lined with concrete or equivalent non-porous material
- the treatment of runoff from permanent solid manure storage facilities lined with concrete or equivalent non-porous material

VFS systems are typically suitable for small to medium-sized operations, due to the quantity of runoff generated and the size of the VFS system components required. VFS systems can also work for large operations; however, larger pumps, piping systems, etc. may be needed.

It is very important to note that all other types of wastewater (e.g., milking centre washwater, etc.) and clean runoff (e.g., rainfall water from roofs, unpolluted surface runoff) generated on-farm must be excluded from VFS systems at this time. This is due to:

- permitting issues
- increased loading issues
- unnecessarily high loading rates of clean water

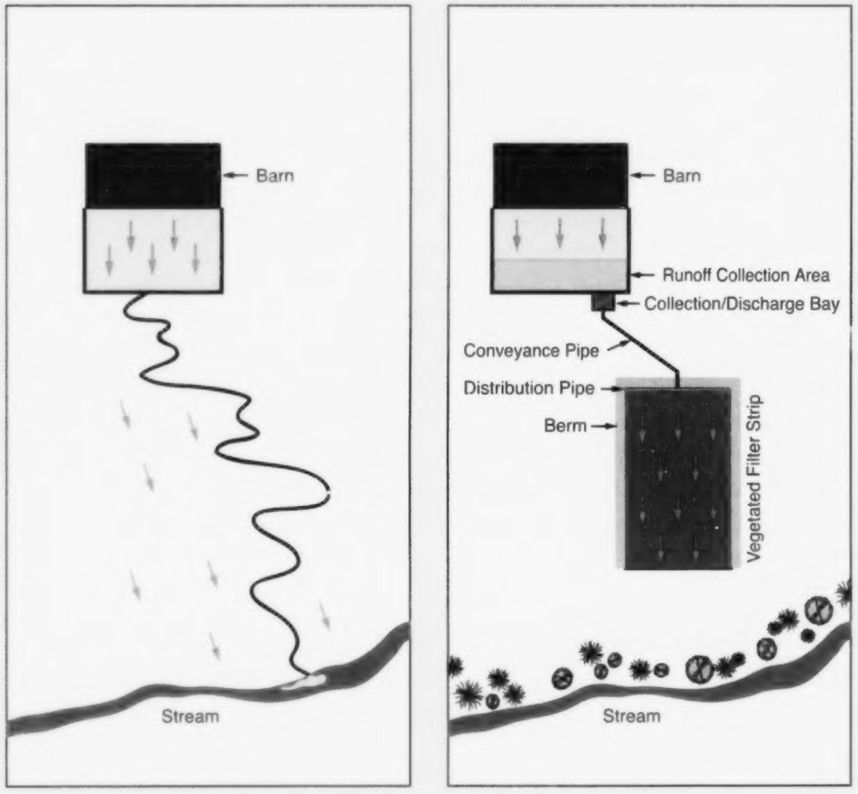
1.4 Definition of VFS System

A VFS system collects, temporarily stores, and transports agricultural runoff generated from an outdoor livestock yard/outdoor confinement area or a permanent solid manure storage facility to an infiltration area. The VFS system is composed of a series of components that serve the following primary functions:

1. Collect and temporarily store agricultural runoff
2. Screen out solids from agricultural runoff
3. Control rate of release of nutrients, organic matter, and pathogens in agricultural runoff
4. Transport agricultural runoff to an infiltration area (via gravity or pump)
5. Distribute flow evenly across infiltration area
6. Allow runoff to infiltrate into soil within infiltration area

The infiltration area is a densely vegetated (planted) strip of land, engineered and constructed to accept and manage runoff through settling, filtration, absorption and infiltration processes. The VFS system is designed to be "zero discharge." This means that the VFS system accommodates all of the agricultural runoff that it receives, without discharging any to surface water. Limitations are outlined in this manual to ensure that ground water quality is also protected.

Figure 1.1
"Before" and "after" schematic



Before **After**

1.5 Alternatives to VFS System

A runoff management system for a permanent solid nutrient storage facility, a concrete-lined farm yard, or a permanent outdoor confinement area should be capable of preventing, collecting, treating, or containing runoff and consist of at least one of the following components.

1.5.1 Roof

Covering the entire area will prevent entry of precipitation, when upslope water has also been diverted away from the facility or yard. Clean roof runoff does not require treatment, and therefore no additional runoff management would be required if the area is covered. It is good practice to prevent rainwater from entering the feedlot by using gutters and downspouts to handle water from building rooftops.

1.5.2 VFS System or Equivalent

Vegetated filter strip systems or an equivalent system, e.g., constructed wetland, both of which are designed by a qualified professional and capable of minimizing the effect of runoff on surface water, are acceptable runoff management systems.

1.5.3 Storage and Land Application

Runoff collection and storage systems must have the capacity to contain runoff generated by the facility, yard, or area, as the case may be, for the storage period required of 240 days, or as required by Section 69 of Regulation 267/03, as amended. Livestock yard and permanent solid manure storage runoff could be collected and conveyed to liquid manure or dedicated storage facilities for subsequent land application, or directly land applied. Phased-in operations must meet the requirements of the Nutrient Management Act, and associated Regulation and Protocols, including the storage period required by Section 69 of Regulation 267/03, as amended (240 days with exceptions, depending on the period of use of an outdoor containment area, nutrient application schedule, temporary storage units, transfers out, etc). For farms with Nutrient Management Plans, the nutrient content of the land-applied runoff must be accounted for in the plan.

1.5.4 Permanently Vegetated Area

If upslope water is diverted away from the facility, yard or area, a permanently vegetated area may be an option for managing runoff. This option does *not* apply to the following facilities:

(a) a permanent solid nutrient storage facility where the runoff generated by 300 m^2 (3,229 ft^2) or more of the facility is channelled through a single flow path;

(b) a permanent outdoor confinement area where the number of farm animals kept in the area is sufficient to generate at least 150 nutrient units annually; or

(c) a permanent outdoor confinement area where the runoff generated by 2,000 m^2 (21,528 ft^2) or more of the confinement area is channelled through a single flow path.

In addition, the permanently vegetated area must be located on a minimum of 0.5 m (1.6 ft) of soil and must meet a number of restrictions for setback distances and flow path requirements. Consult Regulation 267/03, as amended, Section 81 for specific details.

1.5.5 Alternative Management Options

Similar to the management of other nutrients, alternative management includes:

- transferring runoff to other farm units for storage and land application
- designing and building an on-site treatment facility
- using other natural treatment systems such as wetlands
- using a broker for management

These alternative management options do not replace the requirements of Section 81 of Regulation 267/03, as amended.

1.6 Abbreviations

BMP	Best Management Practices
MOE	Ontario Ministry of the Environment
NMA	Nutrient Management Act, 2002
NMP	Nutrient Management Plan
NMS	Nutrient Management Strategy
NU	Nutrient Units, as defined under the NMA
OCA	Outdoor Confinement Area
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
OWRA	Ontario Water Resources Act
VFS	Vegetated Filter Strip

1.7 Regulatory Framework

1.7.1 Legislation

The Nutrient Management Act, 2002 (NMA) sets clear and consistent standards for managing nutrients on farms. The act is intended to be a detailed province-wide approach to managing all nutrients on agricultural land. The goal of the act is to protect soil and water quality in Ontario's rural environment, ensuring farmers can invest in and operate their farms with confidence. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the Ministry of the Environment (MOE) are responsible for governing the act, as well as the 12-part Regulation (Ontario Regulation 267/03, as amended) that outlines standards and the two protocols (Nutrient Management and Sampling & Analysis), which provide more detail to the Regulation. The Regulation and related protocols were enacted July 1, 2003, and came into effect September 30, 2003.

The Regulation addresses the management of manure, and other prescribed materials, that can be land applied to enhance crop production. A Nutrient Management Strategy (NMS) is a document prepared by agricultural operations that generate nutrients. The NMS describes the volume and characteristics of those materials, as well as how they should be stored and utilized. A Nutrient Management Plan (NMP) documents how the nutrients should be applied to the land. Specifically, it is an assessment of what application rate is appropriate for the land base, and the crops to be grown, as well as any other standards that must be followed, such as separation distances or waiting periods.

Nutrient Units (NU) are utilized to categorize the size of farms, and relate to the implementation schedule for NMS and NMP. A nutrient unit is the amount of manure that gives the fertilizer replacement value of the lower of 43 kg (95 lb) of nitrogen or 55 kg (121 lb) of phosphate. Table 3.1 in the Nutrient Management Protocol can help determine the number of NU on a farm. The total number of NU will determine whether a livestock operation is regulated.

As of December 31, 2005, all farm operations that apply for a building permit for any building or structure that is used to house farm animals or to store manure, or that construct an earthen storage, will require an approved NMS from OMAFRA if there are more than five NU on the farm unit. Consult the OMAFRA website at *www.omafra.gov.on.ca* or call the Nutrient Management hotline at 1-866-242-4460 for more precise information on phasing in of farm operations.

Once an agricultural operation is captured by the Regulation (e.g., it is required to comply with the NMS and NMP in place), the farm owner/operator is also responsible for managing runoff associated with the storage of nutrients. This means that, once an NMS or NMP is required by the Regulation, a permanent solid nutrient storage facility must have a runoff management system. An outdoor confinement area or an impermeable farm animal yard must also be equipped with a runoff management system. Section 81 of Regulation 267/03, as amended, provides specific details.

A runoff management system must be capable of handling all the runoff generated by a farm animal yard or permanent solid manure storage facility. A vegetated filter strip system, designed by a qualified professional, is recognized by Regulation 267/03, as amended, as an appropriate runoff management system. This manual provides guidance for the design, construction and operation of a VFS system.

1.7.2 Approval Process

Under Section 53 of the Ontario Water Resources Act (OWRA), as of January 2006, farmers require approval for the installation of a VFS system. For any installations being installed, farmers must apply for and comply with the Certificate of Approval issued under the OWRA by the Ministry of the Environment (MOE). There is no fee for applying for this Certificate of Approval. Issuing an OWRA approval can take a significant amount of time so it is important to plan the VFS system well in advance.

A new process has been introduced whereby applications for Certificate of Approval for installation of VFS systems will be submitted to OMAFRA for technical review. OMAFRA will provide recommendations to the MOE for consideration for approval. This should streamline the system, so that approvals can be issued in a timelier manner. The MOE would still issue the Certificate of Approval. For updates, check the OMAFRA website at *www.omafra.gov.on.ca* or contact an OMAFRA resource centre.

1.8 Funding Assistance

Funding assistance is available for farmyard runoff control projects through the Canada-Ontario Environmental Farm Plan Program. The Ontario Soil and Crop Improvement Association administers the funding and overall delivery of the federal funding program.

By accessing federal funding, farmers are eligible for assistance of 50 per cent of the cost of a vegetated filter strip system to a maximum of $20,000.

For more information on the federal funding available and to apply for funding, contact the OSCIA at *www.ontariosoilcrop.org* or 1-519-826-4214.

1.9 Best Management Practices/Related OMAFRA Literature

OMAFRA has a number of Best Management Practices books available, including:

- *Buffer Strips* (BMP 15)
- *Manure Management* (BMP 16)
- *Nutrient Management* (BMP 05)
- *Nutrient Management Planning* (BMP 14)
- *Soil Management* (BMP 06)
- *Water Management* (BMP 07)

Fact sheets are also available from OMAFRA on the following VFS system–related topics:

- *Nutrient Management Act, 2002, Siting Regulations for Manure Storage Facilities* (Order No. 06-021)

Additional fact sheets on other topics include:

- *Handling Milking Centre Washwater in an Environmentally Responsible Manner* (Order No. 04-019)
- *Nutrient Management Act, 2002, Constructing Hydraulically Secure Liquid Nutrient Storage Facilities* (Order No. 06-035)

BMP books and fact sheets are available through OMAFRA resource centres, or from the OMAFRA website at *www.omafra.gov.on.ca*.

1.10 Utilization of Professional Design, Engineering, Site Assessment, and Construction Services

Farm owners/operators and other rural landowners will be required to retain professional services for investigation, design development, and possibly construction of a VFS system. These services may include a professional engineer, hydrogeologist, geoscientist, laboratory and/or contractor.

Information on selecting and retaining professional services can be obtained from the following OMAFRA fact sheets:

- *Hiring a Practicing Professional Engineer for Farm Projects* (Order No. 95-027)
- *How to Choose a Consultant: A Resource for Your Community or Organization* (Order No. 98-053)

OMAFRA resource centres can provide a list of laboratories suitable for soil sampling or check the OMAFRA website at *www.omafra.gov.on.ca.*

2 General Design Guidance for VFS System Components

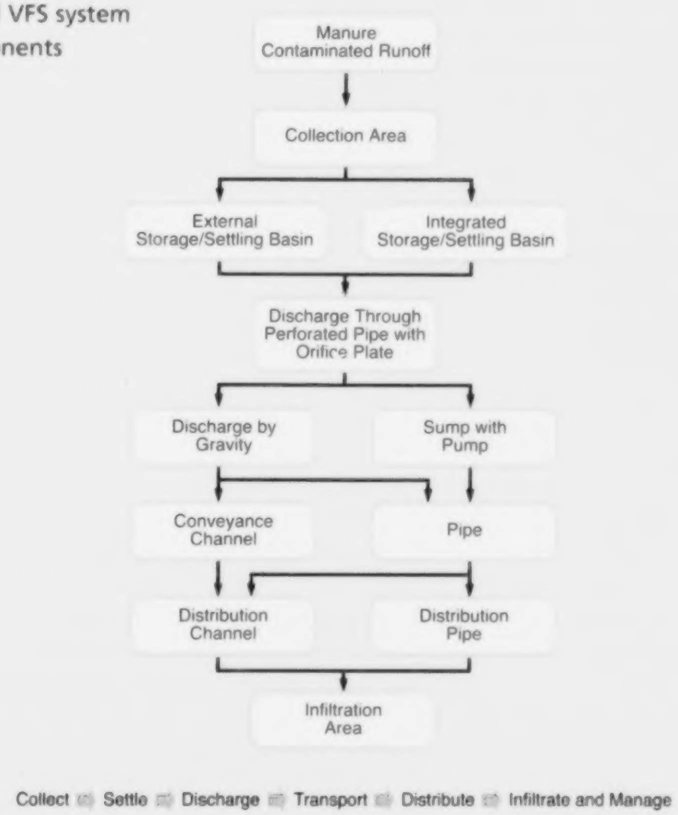
2.1 Description of VFS System Components

A VFS system consists of a series of components that collectively provide the following key functions:

- collect and temporarily store runoff
- screen or settle solids from runoff
- discharge runoff at a controlled rate
- convey runoff
- distribute runoff evenly across the infiltration area
- allow runoff to infiltrate within a defined vegetated area

An overview of the VFS system components and possible configuration variations are shown in Figure 2.1. A detailed description of the individual VFS system components is outlined in this section.

Figure 2.1
Typical VFS system components


Manure Contaminated Runoff
Collection Area
External Storage/Settling Basin
Integrated Storage/Settling Basin
Discharge Through Perforated Pipe with Orifice Plate
Discharge by Gravity
Sump with Pump
Conveyance Channel
Pipe
Distribution Channel
Distribution Pipe
Infiltration Area
Collect ⇨ Settle ⇨ Discharge ⇨ Transport ⇨ Distribute ⇨ Infiltrate and Manage

2.1.1 Runoff Collection Area

The area from which runoff is generated and collected is called the "runoff collection area." Runoff is generated when rainwater comes into contact with and begins to convey dissolved or suspended nutrients and contaminants away from the manure storage or feedlot area. Runoff may also include other sources, such as water used to clean outdoor livestock yard/confinement areas. This design manual considers only runoff collection areas associated with livestock yards/confinement areas or permanent solid manure storage facilities that meet the following criteria. They are:

- situated outdoors
- uncovered (for example, no roof)
- consist of a non-porous surface (e.g., concrete)

The runoff collection area surface must be made of a non-porous surface (such as concrete) that is watertight. Runoff collection areas with imperfect non-porous surfaces will need to be corrected before being considered suitable as a runoff collection area. The existing surface may need cracks to be repaired using a polymer-based concrete sealing compound, or the surface sealed using a silicon based sealant. Runoff areas with soil-based surfaces will require the installation of a non-porous surface in order to be considered suitable for runoff management using a VFS system.

Management of manure in the outdoor livestock yard/confinement area or permanent solid manure storage facility is critical to the success of the VFS system. In an outdoor livestock yard/confinement area, farmers must regularly clean the surface. In a permanent solid manure storage facility, it is important to properly place the solid manure in the runoff collection area so that the manure pile is concentrated upslope and outside the runoff storage area, whenever possible.

2.1.2 Runoff Storage/Settling Basin

This manual describes two options to accommodate storage of the runoff that is collected from the runoff collection area. The runoff storage basin can be either integrated into or external from the outdoor livestock yard/confinement area or permanent solid manure storage area as described in the following:

1. ***Integrated Storage.*** In this scenario, runoff is stored directly within the outdoor livestock yard/confinement area or permanent solid manure storage area by constructing a sufficiently high containment wall around all or a portion of the area, serving to retain the required storage volume. The runoff collection area must have sufficient slope (from the highest point to the lowest collection point) to generate the required storage volume if a containment wall is erected around it. The extent of the runoff collection area should be assessed to ensure that adjacent barns or other existing structures are not flooded during severe storm events. An additional 0.3 m (1 ft) of freeboard height (e.g., excess wall height above design requirement depth to serve as safety factor) is incorporated into the wall height to accommodate the required runoff storage volume plus an additional 0.15 m (0.5 ft) of height is added to accommodate the provision of an emergency overflow spillway.

2. ***External Storage.*** In this scenario runoff is stored in a concrete (or equivalent) chamber or basin, downslope of the runoff area that is large enough to accommodate the required storage volume. External storage may be provided in a suitable existing (and modified if required) facility or in a purpose-built facility. An additional 0.3 m (1 ft) of freeboard height and another 0.15 m (0.5 ft) of spillway height must be added to the basin depth/height to contain the required runoff storage volume. The extent of the storage volume is equivalent to the usable (live storage) volume of the basin and excludes any standing water (dead storage). A minimum standing water depth (dead storage) of 1 m (3.3 ft) is required to allow for storage of settled solids and to minimize re-suspension of settled solids during storm events.

The runoff storage basin also serves to facilitate settling of coarse materials contained in the runoff. The settling is achieved by maintaining a minimum holding time of the runoff generated in the runoff storage area so that the solids can settle out of the water via gravity. In both integrated and external storage scenarios, a minimum 15-minute retention time during peak flow periods is required (for example, runoff must be contained in storage for at least 15 minutes before it is discharged, to allow solids to settle).

The storage volume in a permanent solid manure storage area must take into consideration the loss of water storage volume due to the presence of solid manure. If a significant portion of the permanent solid manure storage area contains solid manure, additional runoff storage volume must then be generated to compensate for the loss of runoff storage capacity. Regular cleaning of the manure storage area will be required to reduce the potential for overtopping the storage area with runoff due to an excessive buildup of manure. Overtopping the storage area would constitute a spill and could lead to action against the landowner by the regulators.

Farmers may achieve significant savings if the runoff storage basin is integrated into the outdoor livestock yard/confinement area or permanent solid manure storage area. The capital costs associated with the construction of an integrated containment wall is expected to be low compared to the capital costs associated with the construction of a new concrete or earthen external storage/settling basin. Either a concrete or earthen external storage/settling basin may be used provided that as part of a vegetated filter strip system, it is capable of minimizing the effect on surface and ground water. The use of existing storage facilities would make the external storage/settling basin scenario significantly more viable from a cost perspective, assuming that the existing facility is situated downstream of the runoff collection area, and is suitable for storage of runoff. One would not be able to enter an earthen storage basin with equipment for cleaning. Sludge is removed with a backhoe.

The integrated system is the more practical system to accommodate storage of the runoff.

2.1.3 Runoff Collection/Discharge System

A runoff collection/discharge system, situated at the lowest point of the runoff collection area, is used as the principal discharge outlet. In an integrated storage/settling basin design, a collection/discharge bay is integrated into the containment wall. The collection/discharge bay will contain an orifice plate and a drainpipe outlet that controls the rate of discharge of stored runoff into a sump. Typically, the collection/discharge bay will consist of four primary components:

- Screens are installed upstream of the drainpipe outlet to minimize the potential for clogging of downstream system components by debris and particles. Three screens are recommended, with an increased level of screening (reduced screen openings) as the runoff flows through them toward the drainpipe outlet. The bar spacing for each screen becomes smaller to progressively capture smaller particles. Typically, screens are installed in vertical channels to allow for easy removal and to facilitate cleaning. The material used to construct the screen may range from prefabricated metal screens (2 cm (0.75 in.)) or heavy quarry screens (with about 2.5–3.8 cm (1-1.5 in.) openings), to wooden picket fence–style screens. Screens may also be installed on an angle. Installing the screens on an angle and providing for a “beach” area along the top of the screens will allow for temporary storage of captured material that can be raked off the screens during the cleaning process.
- A vertical perforated riser pipe also acts as a screen.
- An orifice holder is able to accommodate a range of removable orifice plates, the opening size of which controls the rate of discharge from the runoff storage basin. The orifice plate is set flush with the surface of the downslope point of the runoff storage basin.
- A drainpipe transfers the runoff water to a sump.

In instances where the infiltration area is situated adjacent to an integrated storage/settling basin, one or more drainpipes may be installed directly through the containment wall. The drainpipe(s) would be located at the base of the containment wall, at the most down-slope collection point. Screening would be required upstream of the drainpipe(s). The drainpipe would directly discharge to a conveyance channel and be directed to a distribution channel at the head of the infiltration area.

In an external storage/settling basin design, the collected runoff needs to be transferred to the storage/settling basin first. The runoff collection area simply directs flow (via gravity) to a common low point and transfers the runoff to the external storage/settling basin. Runoff can be transferred through a pipe or conveyance channel system to the external storage. In all cases the transfer system must be designed to carry the peak discharge flow from the runoff collection area for a 25-year/5-minute duration storm event. Only a coarse screen, i.e., wood picket fence, would be installed at the runoff exit point of the collection area to prevent coarse materials from entering the external storage/settling basin. A standard curb-and-gutter approach, collection ditch, or containment berm would likely be required around all, or a portion of, the runoff collection area to ensure that all runoff is captured. The external storage/settling basin may be located downslope of the runoff collection area so that gravity can be utilized as the conveyance mechanism.

If there isn't enough slope, the runoff may need to be pumped from the collection point to the external storage/settling basin. In these cases, a sump will be required to accommodate a pump, and screening of solids will be required at the discharge point from the runoff collection area.

2.1.4 Sump

Water discharged through the drainpipe outlet from the runoff storage/settling basin will be directed into a sump. The sump will be installed adjacent to the low point of the storage basin and will be constructed below grade to facilitate year round operation. The sump will be large enough to accommodate a siphon or pump and permit easy access for maintenance purposes. A lockable access hatch must be provided to the sump, helping to restrict access. The pump will be one that can convey large size solids such as a wastewater sludge rated pump (for example, a screw-induced flow centrifugal pump).

There are several different types of pre-fabricated sumps available that are composed of various types of material (concrete, metal, plastic, fibreglass, etc.) that can be used.

2.1.5 Conveyance Pipe

The function of the conveyance pipe is to convey the runoff in the sump to the distribution pipe or distribution channel and eventually the infiltration area. The conveyance pipe will accomplish this either with a gravity system using a siphon, or by means of a pump.

Gravity System—Piped

The use of a gravity system will be dependent upon the change in grade that exists from the sump outlet elevation to the discharge elevation of the distribution pipe at the inflow end of the infiltration area. The change in grade must be sufficient enough to generate adequate flow velocities (minimum of 0.6 m/s (2.0 ft/s)) in the pipe during the conveyance of the runoff water to the infiltration area, to prevent deposition of solids in the conveyance pipe. If insufficient grade change exists, then a pumped system will need to be used. The vast majority of VFS system applications do not rely on gravity for flow, but rather on pumps to move runoff to the infiltration area, due to generally inadequate grade differentials.

Where grade changes significantly, a siphon-like piping arrangement is recommended to allow dosing of flow from the sump to the infiltration area. Siphons work using only air, water pressure, and gravity. Dosed flow will reduce the potential of solids settling in the pipe during low-intensity flow events and improve the distribution of the runoff water across the full width of the infiltration area to promote even sheet flow. There are several automatic dosing systems and floating outlet devices available for purchase for this specific application. These systems require regularly scheduled maintenance and monitoring to ensure the long-term reliability of their performance.

Gravity System—Channel

Where the following conditions can be met, a conveyance channel may be used to move flow from the runoff storage area to the infiltration area:

- infiltration area is situated within 20 m (65.6 ft) of the runoff area
- gravity discharge through the containment wall (from the low point in the runoff storage basin) is possible
- there is sufficient grade change between the runoff storage basin to the infiltration area, generating an adequate flow velocity

The use of a vegetated conveyance channel configuration has a few advantages that may significantly lower the costs associated with the construction of the VFS system. However, there are many more significant maintenance and operational considerations that need to be weighed against cost savings. The conveyance channel may need to be properly lined to prevent infiltration to ground water. The slope of the conveyance channel must be large enough to permit adequate surface flow; otherwise, deposition of solids will likely occur, requiring occasional removal. If the existing grade change is too large, significant effort may be required to protect the conveyance channel from erosion through the use of energy dissipation measures, e.g. rock riprap. Early and late winter operating conditions may render the channel unusable due to ice cover. A distribution channel would need to be used in conjunction with the conveyance channel (at the upstream end of the infiltration area) to promote sheet flow across its full width.

Pumped System

In a pumped system, the conveyance pipe will be flowing under pressure from the sump to the distribution pipe. Typically, pumps selected will be submersible pumps that are located in a sump of suitable depth to allow sufficient head (water height) above the pump for it to operate and to prevent freezing of the water in the sump well. Pumps should allow for passage of up to 5.0 cm (2 in.) solids, such as commonly available sewage pumps (for example, screw-induced flow, centrifugal pumps).

Size of the pump will depend on its ability to keep pipe velocities below 1.5 m/s (5 ft/s), and to match the required outflow rate from the storage basin and the head differential between the pump inlet elevation and the distribution pipe outlet elevation.

Winter freezing conditions must be accounted for in the design of either type of conveyance pipe system. The conveyance pipe must be installed below frost depth to ensure that flow through the pipe can be accommodated year round, if required.

2.1.6 Distribution Pipe

The function of the distribution pipe is to evenly distribute flow from the runoff collection basin across the full width of the inflow end of the infiltration area in order to promote sheet flow.

Flow from the conveyance pipe is directed into the distribution pipe situated along the full width of the infiltration area. The distribution pipe should be elevated above an erosion-proof pad. Flow from the conveyance pipe is accommodated through a series of orifice openings across the distribution pipe length. A gravel filled channel should be utilized at the upstream end of the infiltration area where there is insufficient slope to accommodate an elevated distribution pipe. This type of arrangement is appropriate when a containment wall runoff storage basin is located adjacent to the infiltration area.

2.1.7 Erosion-Proof Pad

An erosion-proof pad receives the water emitted from the distribution pipe orifice openings. The erosion-proof pad functions as an energy absorption device as well as to further distribute flow to reduce the potential of rills or gullies forming. Typically, a concrete slab (e.g., patio slab or silo stave) would be used to break the fall of the water exiting from the distribution pipe.

2.1.8 Infiltration Area

The infiltration area is a densely vegetated strip of land designed to accommodate infiltration of 100 per cent of the runoff generated from the runoff area during the design-storm event.

The minimum area required for the infiltration area is determined by the rate of flow to the infiltration area from the runoff collection area, and the saturated hydraulic conductivity of the soil.

Saturated hydraulic conductivity is a measure of the rate at which water infiltrates through the soil under saturated (wet) conditions.

The minimum size and dimensions of the infiltration area are also determined by the slope of the infiltration area and the depth of flow over the infiltration area.

As a final check, the size and dimensions of the infiltration area are also calculated based on permitted maximum weekly liquid loading levels.

2.2 Assessment of Farmstead Site Conditions Related to Design of VFS System

The viability of a VFS system will depend upon each farmstead's individual site-specific characteristics. An assessment of those characteristics is required to define design parameters associated with certain components of the VFS system. This information related to the farmstead is required to define the configuration of the VFS system components. The following is a list of the information that needs to be collected:

- runoff collection area characteristics (establish extent of collection area)
- storage area characteristics (establish use of integrated or external storage/settling basin)
- topographical relief characteristics (establish whether system can operate via gravity or require a pump)
- infiltration area characteristics (establish suitable land area for infiltration area)

2.2.1 Runoff Collection Area Characteristics

An assessment of the area contributing runoff should be carried out. The assessment will involve the following:

- Establish Extent of Area Contributing Runoff to the VFS System—The dimensions of the outdoor portion of the livestock yard/containment area or solid manure storage facility contributing runoff must be measured to determine the total area contributing runoff.
- Identify Clean Water Contributions and Establish Potential Alternate Routes—Uncontaminated upslope water should be prevented from entering the runoff area. This includes roof water and overland flow that has not been in contact with livestock manure. This uncontaminated water does not require treatment.
- Redirect Other Wastewater Contributions to Appropriate Treatment Facilities—Milking centre washwater or wastewater from other sources must be excluded from the VFS system. These types of wastewater require collection and separate treatment and disposal to protect the environment.
- Collect Rainfall Data—Obtain rainfall Intensity-Duration-Frequency (IDF) tables and curves produced from historical rainfall data by Environment Canada for the geographical centre closest to the farmstead.

2.2.2 Storage Area Characteristics

An assessment of the existing outdoor livestock yard/containment area or permanent solid manure storage facility will establish whether an integrated or external runoff storage basin can be incorporated into the VFS system. The assessment will involve the following:

- Establish Structural Integrity of Containment Area Pad Surface—The pad surface must be of concrete or equivalent non-porous material. The integrity of the impervious material must not be compromised by any cracks or other imperfections. If the integrity of the floor is suspect, measures must be taken to ensure that the runoff will not be able to infiltrate through any portion of the pad. For example, farmers may have to pressure-wash, dry-fill joints with a high-strength polymer-based repair cement, and/or apply an epoxy-based liner to seal the surface of the impervious material. Containment walls must be constructed to be watertight, including the joint between the wall and runoff area floor.
- Assess Slope of Floor Surface—The slope of the outdoor livestock yard/containment area or permanent solid manure storage facility surface must be sufficient to direct flow to a low point and allow for sufficient runoff storage volume to be created with the construction of a containment wall. The slope of the surface must be established by:
  - measuring the vertical height of the surface between the lowest and highest point of the surface (rise)
  - measuring the corresponding horizontal distance as measured along a level plane (run) between the lowest and highest point of the surface

- dividing the resulting rise by the run

  For example, if the rise is 0.5 m (1.6 ft) and the run is 20 m (65.6 ft), the slope is 0.5/20 = 0.025 m/m (0.025 ft/ft) or 2.5 per cent.

- Assess Primary Collection Point—The slope of the outdoor livestock yard/containment area or permanent solid manure storage facility surface must direct the runoff to a common collection point at the furthest downslope location. Establish the lowest point and determine if all runoff from the surface will eventually find its way to the low point.
- Assess Flood Potential of Adjacent Structures—Ensure that structures associated with the runoff collection area are not flooded as the water level increases within the outdoor livestock yard/containment area or permanent solid manure storage facility, helping to accommodate the runoff storage volume.
- Program Compatibility—Establish what impact flooding will have on the operation of outdoor livestock yard/containment area or permanent solid manure storage facility. In outdoor livestock yards/containment area, will feeding operation be interfered with during flooding? Can livestock maintain access to a sufficient portion of the yard?
- Operation and Maintenance Considerations—During the design of a VFS system, consideration must be given to accessibility of components that will require operation and maintenance activities. Examples of such components include solids settling area, screens, power source, sump, pump(s) and piping access, etc. Access should be sufficient for the appropriate activity and equipment required, and secured to prevent uncontrolled access, such as by children or animals.

2.2.3 Topographical Relief Characteristics

The topographical relief is an important landform characteristic that will determine whether a gravity flow system can be used or whether a pump will be required to convey runoff water collected in the runoff storage/settling basin to the top end of the infiltration area. The assessment will involve collecting the following information:

- Difference in Elevation—The discharge elevation of the runoff from the runoff storage/settling basin to the top end of the infiltration area will need to be determined.
- Linear Distance of Conveyance Pipe—Establish the distance the conveyance pipe will need to travel from the runoff storage basin to the top end of the infiltration area.

2.2.4 Infiltration Area Characteristics

The extent of the land suitable for the development of an infiltration area is established by applying a series of physical design parameters associated with specific site features of the farmstead. The evaluation will generate an opportunity and constraint map of the farmstead that will eliminate portions that are unsuitable for development of an infiltration area and define those portions of the land where an infiltration area may be viable. The site features to be considered and the associated design parameter requirements are outlined in Table 2.1.

Table 2.1

Evaluation of suitable land to accommodate infiltration area

Site Feature	Design Parameter Requirements
Soil—Texture and saturated hydraulic conductivity	The required infiltration area size is directly related to the saturated hydraulic conductivity of the existing soil and is based on the existing soil's ability to infiltrate all of the runoff directed to it during a defined period of time and for a specific intensity storm event, resulting in zero discharge for the maximum design storm event. The saturated hydraulic conductivity is assessed using soil texture measurements and on-site evaluation. In general, the finer the soil texture, the lower the saturated hydraulic conductivity, and the slower the infiltration rate, the larger the area of infiltration required to manage the runoff.
Topography/ Grade	The infiltration area requires sheet flow over the surface for even flow distribution. Therefore, the infiltration area must be flat across its width. Grading may be required to achieve the desired sheet flow across the infiltration area. The infiltration area requires utilization of the entire surface area to best manage and utilize the runoff that is directed to it. Slope along the length must be consistent and between 2% (minimum) and 12% (maximum). The steeper the slope of the infiltration area, the longer will be the minimum length required.
Overburden to Ground Water	The infiltration area requires percolation of the runoff through the soil depth before reaching saturated soil conditions (the water table) of at least 0.9 m (2.95 ft). The depth to ground water must therefore be greater than 0.9 m (2.95 ft). This depth to ground water must be ensured within a 10 m (32.8 ft) zone around the perimeter of the infiltration area. Measurement of distance to ground water, if not known, should be made during mid-spring, likely in May, to provide maximum protection of the ground water.
Overburden to Bedrock	The infiltration area requires percolation of the runoff through the soil depth of at least 0.5 m (1.6 ft). The depth to bedrock therefore must be greater than 0.5 m (1.6 ft). This depth to bedrock must be maintained within a 10 m (32.8 ft) zone around the perimeter of the infiltration area.
Distance from Wells	The infiltration area must be located to satisfy the following conditions: • at least 100 m (328.08 ft) from a municipal well • at least 15 m (49.2 ft) from a drilled well that has a depth of at least 15 m (49.2 ft) and a watertight casing to a depth of at least 6 m (19.7 ft) • at least 30 m (98.4 ft) from any other well not defined above

Site Feature	Design Parameter Requirements
Distance from Surface Water	The infiltration area must be located to satisfy either (a) or (b) below: (a) A flow path of at least 50 m (164.0 ft) in length from the lower edge of the infiltration area to the top of the bank of the nearest surface water (includes vegetated buffer) or tile inlets **or** (b) A vegetated buffer zone adjacent to the top of the bank of the surface water with a minimum width as specified by the infiltration area slope below; **Infiltration Area Slope** — **Minimum Buffer Width** 2 to <4% — 10 m (32.8 ft) 4 to <6% — 20 m (65.6 ft) 6 to <8% — 30 m (98.4 ft) 8 to <10% — 40 m (131.2 ft) 10 to 12% — 50 m (164.0 ft)
Floodplain Boundary	The infiltration area must not be located in an area that is subject to flooding once or more every 100 years, according to floodplain mapping provided by a municipality or conservation authority having jurisdiction over the area. If floodplain mapping is not available, the farm operator must consult with the local conservation authority, the municipal office or local MNR office to determine the location of the 100-year floodplain boundary.
Tile Drained Land	The infiltration area must not be located within 3 m (9.8 ft) of field tile drains.
Buried Refuse	Any edge of the infiltration area must be located at least 20 m (65.6 ft) from an area with buried refuse.
Land Accessibility	Free access grazing is not permitted on the infiltration area. The ability to control livestock access by means of fencing is required. The infiltration area may be suitable for grazing only for a limited time during dry periods of the summer. Care must be taken to ensure animal access does not affect the surface of the infiltration area, which may impact the ability to maintain sheet flow across it and reduce infiltration as a result of compaction.
Woodlot	An existing woodlot is not suitable for an infiltration area.

Establishing an Opportunity and Constraints Map for the Infiltration Area Assessment

The farmer must establish the preferred location of the infiltration area and the maximum area that can be dedicated to it. For design and record-keeping purposes, an aerial photograph and a map of the site at a specific scale should be obtained. Potential sources for mapping include an Ontario Base Map (OBM) that typically has a scale of 1:10,000 and 1:5,000 or a National Topographic Map (NTM) that has a scale of 1:50,000 and is available from Energy, Mines and Resources Canada. OBMs can be obtained from the Ministry of Natural Resources Store by calling 1-800-667-1940.

The map of the farmstead should be used to identify each specific site feature and subsequent setback requirements to eliminate unsuitable land. An example of an opportunity and constraints map is illustrated in Figure 2.2.

Figure 2.2

Example of an opportunity and constraints map

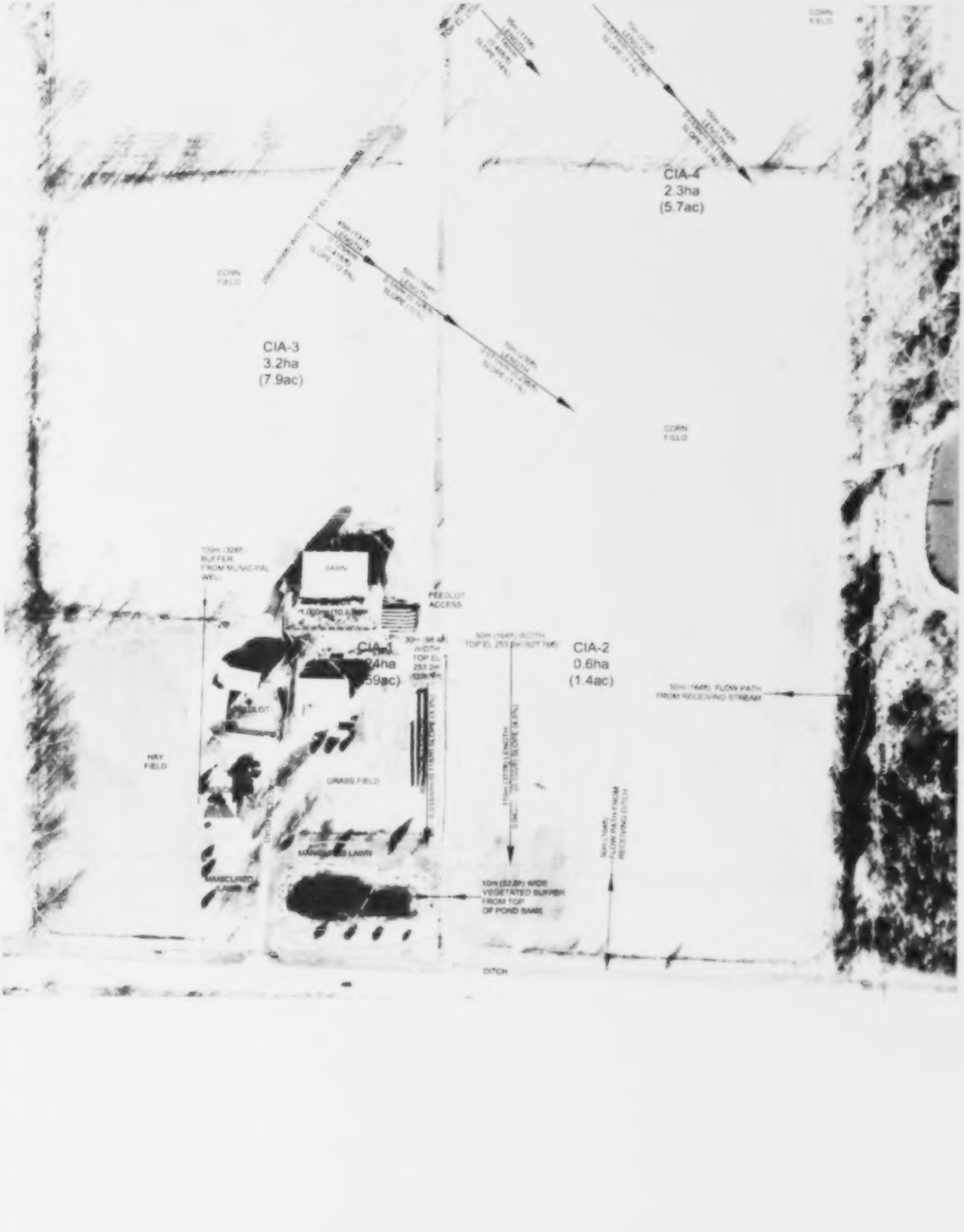
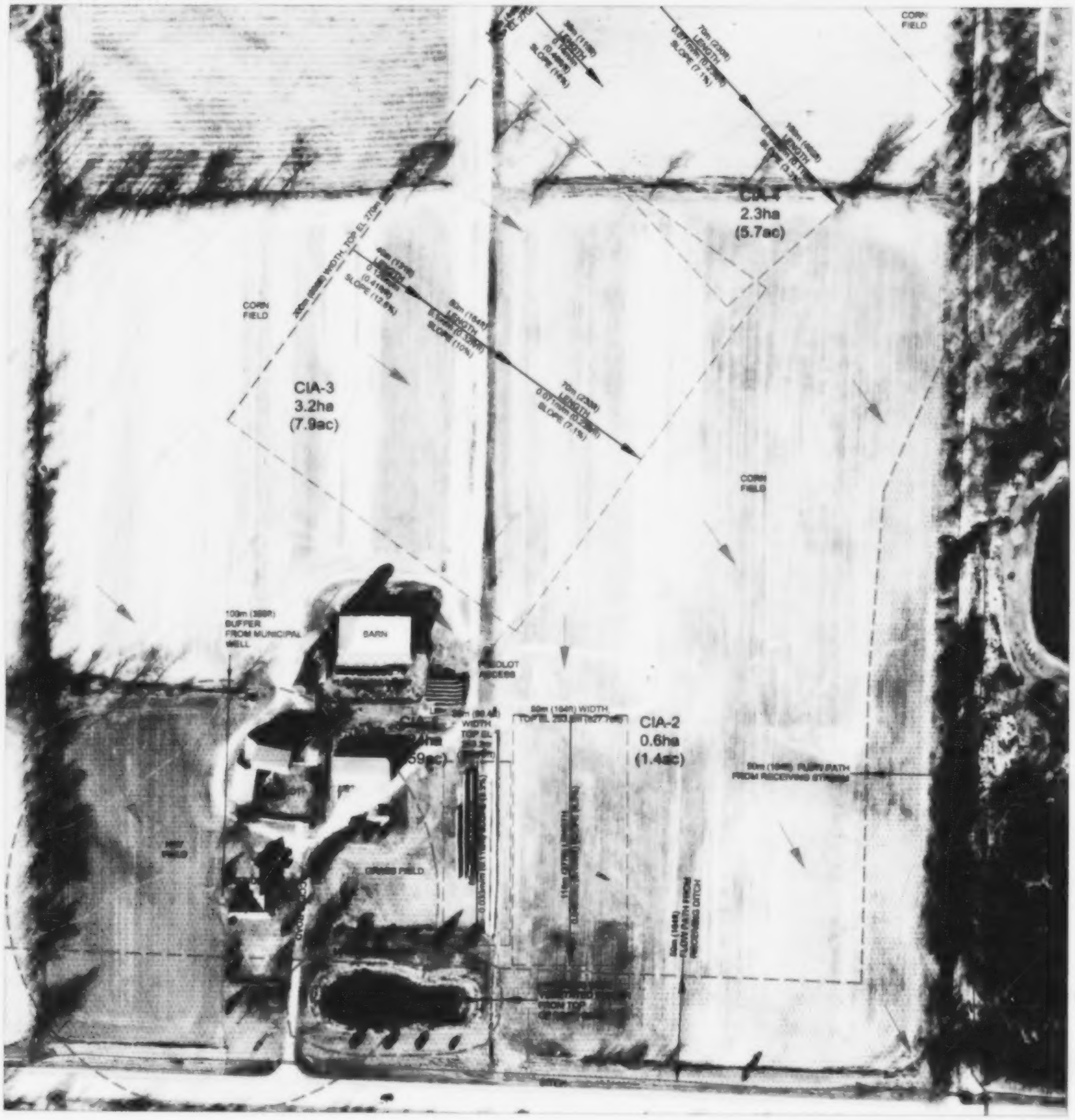


Figure 2.2

Example of an opportunity and constraints map



OPPORTUNITY AND CONSTRAINTS MAP - EXAMPLE

VEGETATED FILTER STRIP (VFS) SYSTEM DESIGN MANUAL "BEEF FEEDLOT APPLICATION"

LEGEND

—	EXISTING GRADES (5.0m INTERVAL)	▨	EXISTING RUNOFF COLLECTION AREA
—	EXISTING RECEIVING WATER COURSES (WETLANDS, RIVERS, CREEKS, DITCHES,)	° LP	EXISTING RUNOFF COLLECTION AREA LOW POINT
▭	EXISTING CULVERT	IA-1	CANDIDATE INFILTRATION AREA
○	EXISTING WELLS (DRINKING WATER)	[ ]	CANDIDATE INFILTRATION AREA SETBACK REQUIREMENTS
→	EXISTING SURFACE WATER DRAINAGE DIRECTION	—	ACCESS REQUIREMENT

IDENTIFY THE FOLLOWING OPPORTUNITY AND CONSTRAINT INFORMATION ON A SCALED MAP/AIRPHOTO

- EXTENT OF RUNOFF COLLECTION AREA
- LOW POINT OF RUNOFF COLLECTION AREA
- ALL EXISTING SLOPES THAT ARE BETWEEN 2 AND 12%
- ALL EXISTING WELL LOCATIONS
- POTENTIAL RECEIVING WATERS
- 100-YEAR FLOODPLAIN BOUNDARY
- SURFACE WATER DRAINAGE PATTERN
- EXTENT OF ANY TILE DRAINED LAND
- LOCATION OF ANY BURRIED REFUSE
- LAND USES ON FARMSTEAD (I.E. TYPE OF CROP)
- ANY WOODLOTS
- ACCESS REQUIREMENTS TO FARMSTEAD, LIVESTOCK BARN AND FEEDLOT/MANURE STORAGE FACILITY

ESTABLISH CANDIDATE INFILTRATION AREAS (CIA) AND ASSESS THE FOLLOWING:

	CIA-1	CIA-2	CIA-3	CIA-4
● SLOPE, LENGTH AND WIDTH, AND AREA	____ % ____ m ____ m ____ m ____ m² ____ m	____ % ____ m ____ m ____ m ____ m² ____ m	____ % ____ m ____ m ____ m ____ m² ____ m	____ % ____ m ____ m ____ m ____ m² ____ m
● SOIL TEXTURE AND SATURATED HYDRAULIC CONDUCTIVITY	____ ____ m/s	____ ____ m/s	____ ____ m/s	____ ____ m/s
● OVERBURDEN TO GROUNDWATER DEPTH	____ m	____ m	____ m	____ m
● OVERBURDEN TO BEDROCK DEPTH	____ m	____ m	____ m	____ m
● WELL TYPE AND SETBACK REQUIREMENT	____	____	____	____
● RECEIVING WATER SETBACK AND/OR BUFFER REQUIREMENT	____ m ____ m	____ m ____ m	____ m ____ m	____ m ____ m

3 Design Guidelines of VFS System Components

This section of the manual outlines the step-by-step procedures for determining and defining the individual components that make up the VFS system. The overall makeup of the VFS system will vary from farmstead to farmstead based on site-specific conditions and, in some cases, individual user preferences. Economic viability is an important factor in the development of the VFS system components. The aim of this manual is to outline a process that generates a functional VFS system at a practical cost. Each step of the design process will outline development alternatives based on site-specific conditions. Criteria will be defined to establish minimum design objectives for each component of the VFS system. The following are the primary components that will be discussed in detail:

- runoff collection area
- storage/settling basin
- collection/discharge system
- conveyance pipe
- distribution system
- infiltration area

3.1 Calculate Runoff Quantity

The first step in designing a VFS system is to determine the quantity of runoff generated from an outdoor livestock yard/confinement area or permanent solid manure storage facility, so that the runoff storage/settling basin can be sized appropriately.

3.1.1 Establish Extent of Runoff Collection Area Contributing Runoff

The extent of the runoff collection area is determined through field observations. The runoff collection area involves the outdoor livestock yard/confinement area or permanent solid manure storage facility that contains manure where runoff is generated. Upslope sources that contribute clean water (e.g., roof drains) and dirty water (e.g., milking centre washwater) to the runoff collection area should be isolated, rerouted, and dealt with appropriately.

3.1.2 Range in Storage/Settling Basin Volume Requirements

The preferred conservative approach establishes a maximum storage volume that accommodates the entire rainfall amount generated within a 25-year storm return period for 24-hour storm duration. The stored volume of runoff must be emptied within four to 10 hours following the storm event. The selection of the appropriate length of time for the runoff volume to empty will vary based on site-specific factors of the livestock yard/ confinement area or manure storage facility. The primary factors involve the extent of flooding during storage periods and the resulting lack of sufficient dry area or access being restricted, requiring a reduced time to empty.

However, there may be instances where there is:

- insufficient existing storage volume capacity available
- a need to reduce the costs associated with the establishment of an external storage/ settling basin
- sufficient suitable land to accommodate a larger infiltration area

At this point, a minimum storage volume equivalent to the peak rainfall rate generated by a 25-year storm return period for 5-minute storm duration with a minimum holding time of 15 minutes may be established.

There are several related consequences associated with the development of a storage/ settling basin that has less capacity than the conservative maximum storage volume. Some of the consequences associated with the smaller storage/settling basin volume relate to the resulting increase in the rate of discharge from the basin to the infiltration area, and the potential to exceed its infiltration capacity. As a result of the shorter holding time in the basin, the following impacts to components of the VFS system can be expected:

- greater capacity pumps
- larger diameter pipes
- greater electrical power requirements (voltage, amperage)
- significantly larger infiltration area

Rainfall amounts and peak rainfall rates are obtained from Rainfall Intensity-Duration-Frequency (IDF) tables. IDF tables and curves produced from historical rainfall data by Environment Canada (for various geographical areas) statistically determine the amount of rainfall in millimetres that would be expected to fall for a given design-storm return period and storm duration. IDF tables ($100 each) are available from Environment Canada, Ontario Climate Centre, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4 or by calling (900) 565-1111 (this is a toll number, with a charge of $3/minute at time of publishing).

3.1.3 Defining Runoff Coefficient

The runoff coefficient is a function of the imperviousness of the floor of the runoff collection area. A runoff coefficient of 0.95 is recommended for VFS system design, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to be discharged to the VFS system. It is anticipated that approximately 5 per cent will evaporate or otherwise escape, or be held up within the VFS system, such as by being absorbed by the solid manure pack and removed with it during routine cleaning.

3.1.4 Calculating Runoff Storage/Settling Basin Volume Requirements

Conservative Method—Maximum Runoff Storage/Settling Volume

The conservative method is a basic method that can be used to calculate the maximum runoff storage/settling volume. Equation 3.1 outlines the variables, units, and mathematical relationship to establish a maximum storage volume. The maximum storage volume is established by multiplying the area of the runoff collection area (A) by the rainfall amount of a storm with a 25-year return period for 24-hour duration (a) by the runoff coefficient (C).

Table 6.1 provides maximum runoff storage/settling volume using the conservative method for selected Ontario centres.

Equation 3.1

Conservative method to calculate maximum storage volume

$$V_{max} = CaA$$

Where: V_{max} = maximum storage volume (m^3)
C = runoff coefficient 0.95
a = rainfall amount 25-yr/24-hr storm event (m)
A = runoff collection area (m^2)

For example, the IDF value for Oshawa shows that a total of 72.7 mm (2.86 in.) of rain will fall during a 25-year return period for a 24-hour duration design-storm event. Therefore, the runoff volume generated from a 1,000 m^2 *(10,764.3* ft^2*) outside concrete livestock yard/confinement area using Equation 3.1 would be equal to (0.95) (72.7 x* 10^{-3} *m) (1,000* m^2*) = 69.1* m^3 *(2,440* ft^3*).*

*From Table 6.1, the storage/settling volume for Oshawa WPCP centre is 69.07*m^3*.*

Rational Method—Minimum Runoff Storage/Settling Volume

The rational method is one method that can be used to calculate the peak discharge and, subsequently, a minimum runoff storage volume. Equation 3.2 outlines the variables, units, and mathematical relationship to establish a peak discharge rate. The peak discharge rate is established by multiplying the area of the runoff collection area (A) by the rainfall intensity of a storm with a 25-year return period for 5-minute duration (i) by the runoff coefficient (C).

Table 6.2 provides minimum storage/settling volume required and peak discharge using the rational method.

Equation 3.2
Rational method to calculate peak discharge

$$q_p = 0.0027CiA$$

Where: q_p = peak discharge (m^3/s)
C = runoff coefficient 0.95
i = rainfall intensity 25-year/5-minute storm event (mm/h)
A = runoff collection area (hectares)

The minimum volume (V_{min}) of runoff required is outlined in Equation 3.3. The peak discharge rate determined by using Equation 3.2 (q_p) is multiplied by the minimum holding time (h_{tm}) of 900 seconds (equivalent to the 15-minute holding time required).

Equation 3.3
Minimum storage volume

$$V_{min} = h_{tm}q_p$$

Where: V_{min} = minimum storage volume (m^3)
q_p = peak discharge (m^3/s)
h_{tm} = minimum holding time of 900 (seconds)

For example, the IDF values for Oshawa show that a 137.4 mm/hour (5.4 in/hour) of rain will fall during a 25-year return period for a 5-minute duration design-storm event. Therefore, the corresponding peak discharge from a 1,000 m^2 *(10,764.3* ft^2*) outside concrete livestock yard/confinement area using Equation 3.2 would be equal to (0.0027) (0.95) (137.4 mm/hr) (0.1 ha) =* 35×10^{-3} m^3/s *(1.24* ft^3/s*). The required minimum storage volume is established using Equation 3.3 and is equal to (*35×10^{-3} m^3/s*) (900 s) = 31.5* m^3 *(1,112* ft^3*).Note that use of the rational method results in approximately half the storage volume as compared to the conservative method.*

From Table 6.2, the minimum storage volume for Oshawa WPCP centre is 31.72 m^3 *(1,120* ft^3*) and peak discharge rate is 0.04* m^3/s *(1.41* ft^3/s*).*

3.2 Design of Storage/Settling Basin

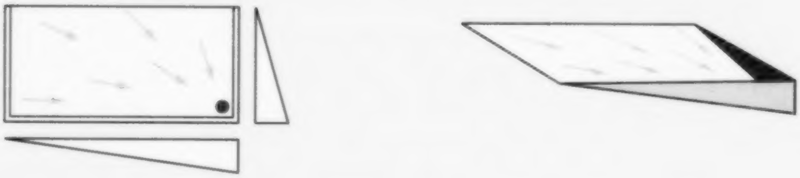
The focus of this manual is on the development of the integrated storage/settling basin within the outside livestock yard/confinement area or permanent solid manure storage facility. This option is the most cost-effective method of providing the desired conservative maximum storage volume. The external storage/settling basin option may be economically viable in instances where an existing storage facility can be utilized or reconfigured to store runoff.

3.2.1 Integrated Storage/Settling Basin Design

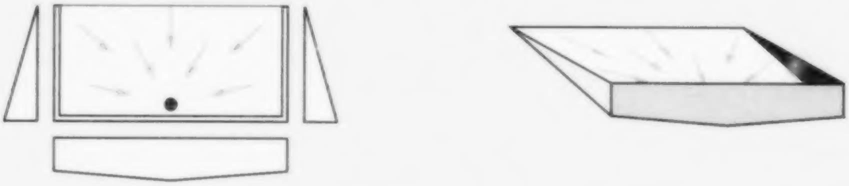
The integrated storage/settling basin is volumetrically defined by the installation of a containment wall around all, or a portion of, the outside perimeter of the runoff collection area. If sufficient slope and area is available to provide the storage, only two walls in a corner, or three walls or a portion of three walls may be required to store the runoff, as shown in Figure 3.1. However, consideration must be given to the extent and depth of the expected maximum water level associated with the conservative maximum storage volume, and an assessment made of the impact on the farming operation, relative to the runoff collection area, that the water level may have.

Figure 3.1
Integrated storage/settling basin—containment wall design options

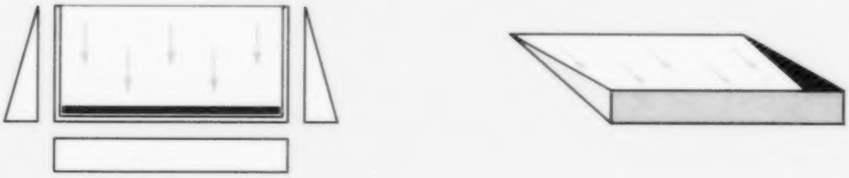
A. Diagonal Cross Slope to a Common Low Point



B. Multiple Slopes to a Common Low Point



C. One Consistent Uniform Slope to a Low Side



Storage Design

The containment wall will be sized to accommodate the required conservative maximum storage volume plus:

- An additional 0.3 m (1.0 ft) of containment wall height will be required to provide sufficient freeboard for events greater than the design storm.
- An additional 0.15 m (0.5 ft) of containment wall height will be required to accommodate an emergency spillway that will direct flow volumes in excess of the 25 year/24-hour storm event to controlled discharge point(s).

The conservative maximum storage volume equivalent to the volume generated by the rainfall amount of a 25-year/24-hour storm event should be provided, if possible. The minimum storage volume required is equivalent to the volume generated by the peak discharge rate of a 25-year/5-minute storm event over a 15-minute period. A reduced storage volume will result in a lower containment wall height.

Note: Solids settle at a rate of approximately 1.2 m/hour (4 ft/hour) and the storage/settling basin must be cleaned frequently to ensure its performance. The required frequency of basin cleaning varies considerably depending on basin size, type of lot surface, amount of manure on the lot surface, and storm runoff characteristics. In most instances, cleaning will be necessary after each large storm. A regular cleaning frequency should be followed and the basin should be designed large enough to store the accumulated solids.

The following outlines the methods to determine the containment wall height.

Method for Establishing Containment Wall Height

For runoff areas with one dominant uniform slope to one side or end, as illustrated in Figure 3.1 (C), the minimum containment wall height is calculated by the method shown in Equation 3.4.

Equation 3.4

Containment wall height

$$h = \sqrt{\frac{2Vs}{L}}$$

Where: h = retaining wall height (m) (at right angle to flow)
V = volume of storage (m^3)
s = floor slope in the direction of flow (m/m)
L = runoff area length at right angles to flow (m)

Note: This equation will work only if there is one dominant slope along either the length or the width of the outside yard.

For example, a runoff collection area having dimensions of width = 20 m and length = 50 m and with a requirement for storage of 69.1 m^3 (2,440 ft^3), a slope of 0.01 m/m (0.01 ft/ft) and a runoff length at right angles to the flow of 50 m (164 ft) will require a containment wall height that is equal to the square root of (2 x 69.1 m^3 x 0.01 m/m/50 m) = 0.17 m (0.56 ft). The total containment wall height including the 0.3 m freeboard and 0.15 m emergency spillway height is 0.62 m (2.0 ft).

The distance that runoff will move up the yard, i.e., width of yard covered with runoff, will be 0.17 m/0.01 m/m = 17 m (55.8 ft).

For runoff storage areas that do not have a consistent and uniform slope, or have uneven floor surfaces, a topographic survey of the runoff storage area will be required. The survey information will be used to generate topographic contours of the runoff storage area so that volumetric measurements can be carried out to establish the required containment wall height to meet the storage/settling basin volume requirements. There are several accepted methods that can be used to establish volume. The methods most commonly used are the average end-area method, the planimeter method, and the average-depth method. The accuracy increases with each method, respectively. A much more accurate method would involve the development of a three-dimensional computer model using terrain modeling software. Alternatively, an overly conservative containment wall height may be established to compensate for variability and irregularities present in the runoff collection area. The containment wall must be extended to ensure capture of runoff from the entire runoff collection area.

3.2.2 External Storage/Settling Basin Design

The external storage/settling basin is a dedicated facility that is constructed outside the runoff collection area. The construction of an external storage/settling basin may need to meet local and provincial design standards associated with the construction of a liquid manure storage facility. An alternative to constructing a new basin could involve the re-engineering of an existing storage facility.

For instances where the external storage/settling basin is the preferred configuration, the following general recommendations should be considered in its design.

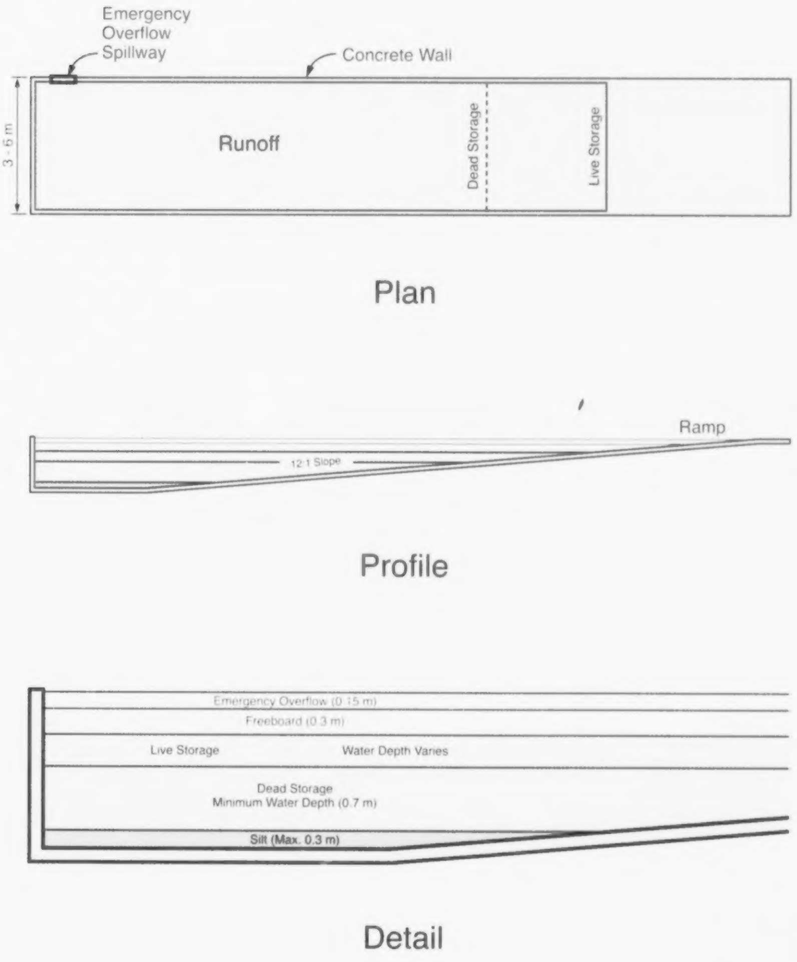
Storage/Settling Basin Design

A minimum storage volume capacity equivalent to the volume generated by the peak discharge rate of a 25-year/5-minute storm event over a 15-minute period must be accommodated. The provision for additional storage capacity will significantly reduce discharge rates and subsequent infiltration area requirements. Figure 3.2 illustrates the volume requirements associated with the development of an external dedicated storage/settling basin. An external storage/settling basin should have a length-to-width ratio of 3 to 1, respectively. The width of the basin should be limited to between 3 to 6 m (9.8 to 19.7 ft) to allow for removal of accumulated silt with reaches associated with standard backhoes.

A total dead storage volume equivalent to a minimum 1 m (3.3 ft) depth of water is recommended to facilitate settling of solids. The dead storage volume will be in addition to the minimum storage volume capacity required to accommodate the volume associated with the peak discharge rate of a 25-year/5-minute storm event over a 15-minute period. The total dead storage volume will accommodate settled solids to a depth of 0.3 m (1 ft) depth and a minimum water depth above the settled solids of 0.7 m (2.3 ft). The minimum water depth above the settled solids will reduce the potential of re-suspending the settled solids during storm event flows. The live storage volume that is needed to accommodate the required storage capacity must be provided for. In addition, once the storage capacity water depth has been established, the storage/settling basin depth should be increased to allow for the provision of freeboard and an emergency overflow. An additional height of 0.3 m (1 ft) is recommended to accommodate the freeboard, and 0.15 m (0.5 ft) is recommended to accommodate an emergency spillway.

Figure 3.2

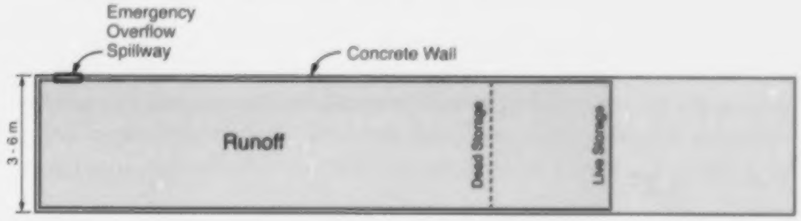
External storage/settling basin profile



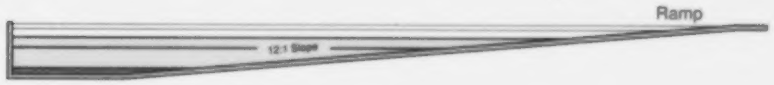
A total dead storage volume equivalent to a minimum 1 m (3.3 ft) depth of water is recommended to facilitate settling of solids. The dead storage volume will be in addition to the minimum storage volume capacity required to accommodate the volume associated with the peak discharge rate of a 25-year/5-minute storm event over a 15-minute period. The total dead storage volume will accommodate settled solids to a depth of 0.3 m (1 ft) depth and a minimum water depth above the settled solids of 0.7 m (2.3 ft). The minimum water depth above the settled solids will reduce the potential of re-suspending the settled solids during storm event flows. The live storage volume that is needed to accommodate the required storage capacity must be provided for. In addition, once the storage capacity water depth has been established, the storage/settling basin depth should be increased to allow for the provision of freeboard and an emergency overflow. An additional height of 0.3 m (1 ft) is recommended to accommodate the freeboard, and 0.15 m (0.5 ft) is recommended to accommodate an emergency spillway.

Figure 3.2

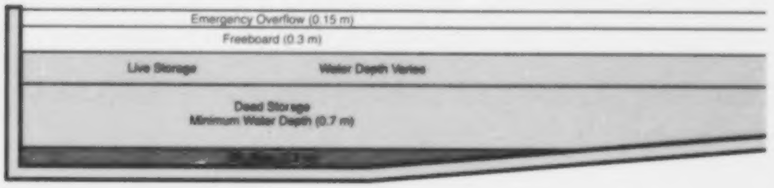
External storage/settling basin profile



Plan



Profile



Detail

Design of External Storage/Settling Basin

There are several configurations possible for the external storage/settling basin. The scenarios include: (i) the installation of a new below grade storage basin, (ii) the utilization of an existing below grade basin, and (iii) the utilization of an above grade storage facility. The use of an existing storage facility will need to be assessed on a case-by-case basis and will not be directly addressed in this manual. The existing structures will need to be modified to conform to the design parameters associated with the external storage/settling basin. For new external storage/ settling basins, consideration must be given to providing the following:

- access for routine removal of solids
- power source for pump (if required)
- fence around facility for safety
- emergency overflow spillway and a preferential flow path that promotes surface sheet flow and avoids direct discharge to receiving waters

Collection Method

In an external storage/settling basin configuration, the runoff that is collected from the yard and permanent solid manure storage areas needs to be transferred to the storage/settling basin as opposed to being managed within the storage/settling basin, as occurs with an integrated storage/settling basin. The runoff collection area directs flow (via gravity) to a common low point, and transfers the runoff to the external storage/settling basin. Runoff can be transferred through a pipe or conveyance channel to the external storage. The transfer system must be designed to handle the peak discharge flow from the runoff collection area for a 25-year/5-minute duration storm event. A coarse screen, i.e., wood picket fence, would be installed at the runoff exit point of the collection area to prevent coarse materials from entering the external storage. A standard curb-and-gutter approach, collection ditch, or containment berm is likely required around all, or a portion of, the runoff collection area to ensure that all runoff is captured. The site survey will determine the best method for directing the water.

The external storage/settling basin may be located down-gradient of the runoff collection area so that gravity can be utilized as the conveyance mechanism. In some instances, insufficient slope may require the runoff to be pumped from the collection point to the storage/settling basin. In cases where the runoff is pumped, a sump will be required to accommodate a pump. Screening of solids should be provided at the collection point from the runoff collection area where pumping is required. The size of the conveyance pipe and the capacity of the pump (if the runoff needs to be pumped to the external basin) would need to be established so that the peak discharge rate associated with the 25-year/5-minute storm event could be conveyed to the external basin.

There are several approaches that could be considered if the proposed collection method is impractical. Consideration could be given to converting unpaved areas to paved yards. This may be appropriate if the newly paved area provides an opportunity to develop an integrated storage basin or provides additional grade difference that reduces the pumping requirement. These are best management practices to consider if the only viable option is to create an external basin. Similarly, the regrading of an unsuitable existing paved runoff area may also be considered as a best management solution.

3.2.3 Emergency Overflow

In the case of extreme storm events that exceed the design-storm criteria, the integrated or external storage/settling basin or the sump may overflow. Under no circumstance should this flow be discharged directly to a watercourse. Emergency overflow spillways must be accommodated in the design of the storage/settling basin to allow the excess runoff to be directed along a predetermined route. An emergency overflow route should be established to generate a preferential flow path that promotes overland sheet flow and avoids potential direct discharge to an adjacent watercourse/receiving stream.

3.3 Determination of Discharge Rates from Runoff Storage/Settling Basin

The discharge rate from the runoff storage/settling basin depends upon the level of storage provided and its configuration as an integrated or external storage facility. The discharge rate from an integrated storage/settling basin can be established using one of the two following methods.

3.3.1 Discharge from an Integrated Storage/Settling Basin

Discharge Rate of Conservative Maximum Storage Volume

In situations where sufficient storage volume can be integrated into the outdoor livestock yard/confinement area or permanent solid manure storage facility, serving to accommodate the conservative maximum storage volume (total rainfall amount generated by a 25-year/24-hour storm event), then the discharge rate will correspond to the total runoff storage/settling volume over a given length of time. The length of time for the discharge of the stored volume will typically extend over a 4 to 10-hour period, depending on the operator's preference. An orifice will be used to establish the desired rate of release. The orifice will be sized to allow the stored volume of runoff to be drained within the minimum period of four hours. Equation 3.5 outlines the variables, units, and mathematical relationship to establish the discharge rate for the various release periods. The discharge rate is calculated by dividing the total storage volume (v_{max}) by the period within which the volume is to be drained from the storage/settling basin (h_{tm}).

Equation 3.5

Calculate discharge rate of conservative maximum storage volume

$$q_{max} = v_{max}/h_{tm}$$

Where: q_{max} = discharge rate for maximum storage volume (m^3/s)
v_{max} = conservative maximum storage volume (m^3)
h_{tm} = holding time (s)

For example, the discharge rate for the conservative maximum volume of runoff of 69.1 m³ (2,440 ft³) released over a 4-hour period is equal to (69.1 m³)/(14,400 s) = 4.80 x 10^{-3} m³/s (0.17 ft³/s). The discharge rate released over a 10-hour period is equal to (69.1 m³)/(36,000 s) = 1.92 x 10^{-3} m³/s (0.07 ft³/s).

From Table 6.1, the discharge rate for a 4-hour period is 4.8 x 10^{-3} m³/s (0.17 ft³/s) and 1.92 x 10^{-3} m³/s (0.07 ft³/s) for a 10-hour period.

Discharge Rate of Volume Less than Conservative Maximum Storage Volume

There may be situations where:

- less than the conservative maximum storage volume can be integrated into the outdoor livestock yard/confinement area or permanent solid manure storage facility but more than the minimum storage volume (total rainfall amount generated by a 25-year/5-minute storm event over a minimum 15-minute holding time) can be retained

In this case, the discharge rate will match the routed peak discharge rate of the 25-year/24-hour storm event. This value can be determined by using Equation 3.6.

Equation 3.6

Flood routing to establish storage/settling basin discharge rate

$$q_o = q_p\left(1.25 - \left[\frac{1500V}{RA} + 0.06\right]^{0.5}\right)$$

Where: q_o = rate of outflow when pipe flows full (m^3/s)
q_p = peak inflow = peak discharge from runoff collection area (m^3/s)
V = available storage volume (ha-m)
R = return period runoff 25-year/24-hour (mm)
A = runoff collection area (ha)

Reference: Soil and Water Conservation Engineering, 3rd Edition, Schwab et al 1996, see page 261

Equation 3.6 outlines the variables, units, and mathematical relationship to establish the discharge rate from the storage/settling basin. Flood routing describes the relationship between peak inflow (q_p), available storage volume (V), runoff amount (R) and drainage area (A), over time. The VFS system should ensure that the storage area will not overflow. This is important where less than the conservative maximum storage volume of the 25-year/24-hour design-storm event is accommodated in the storage basin.

3.3.2 Discharge from an External Storage/Settling Basin

In situations where an integrated storage/settling basin is not feasible and an external storage/settling basin is required, the discharge rate can be established using the principle of flood routing.

Use Equation 3.6 to determine the routed peak discharge flow rate.

For example, an external basin with less than the conservative maximum storage volume that has a peak inflow rate of 35×10^{-3} m^3/s *(1.24* ft^3/s*), available storage of* 3.2×10^{-3} *ha-m (0.026 ac-ft), runoff of 72.7 mm (0.28 in.) and a drainage area of 0.1 ha (0.24 ac) has a rate of outflow from the external storage/settling basin that is equal to* $(35 \times 10^{-3})\,[1.25 - [(1.500)\,(3.2 \times 10^{-3}\ m^3)/(72.7\ mm)\,(0.1\ ha)+0.06]^{[illegible]}] = 14 \times 10^{-3}\ m^3/s$ *(0.50* ft^3/s*).*

In cases where the conservative maximum storage volume of the 25-year/24-hour design-storm event can be accommodated in the external storage, the discharge rate will correspond to the length of time desired to empty the external storage, i.e., 4–10 hours.

In cases where the existing external storage has capacity to hold 1.5 times the storm event, the storage can be emptied over a maximum duration of 24 hours.

3.4 Runoff Collection/Discharge System

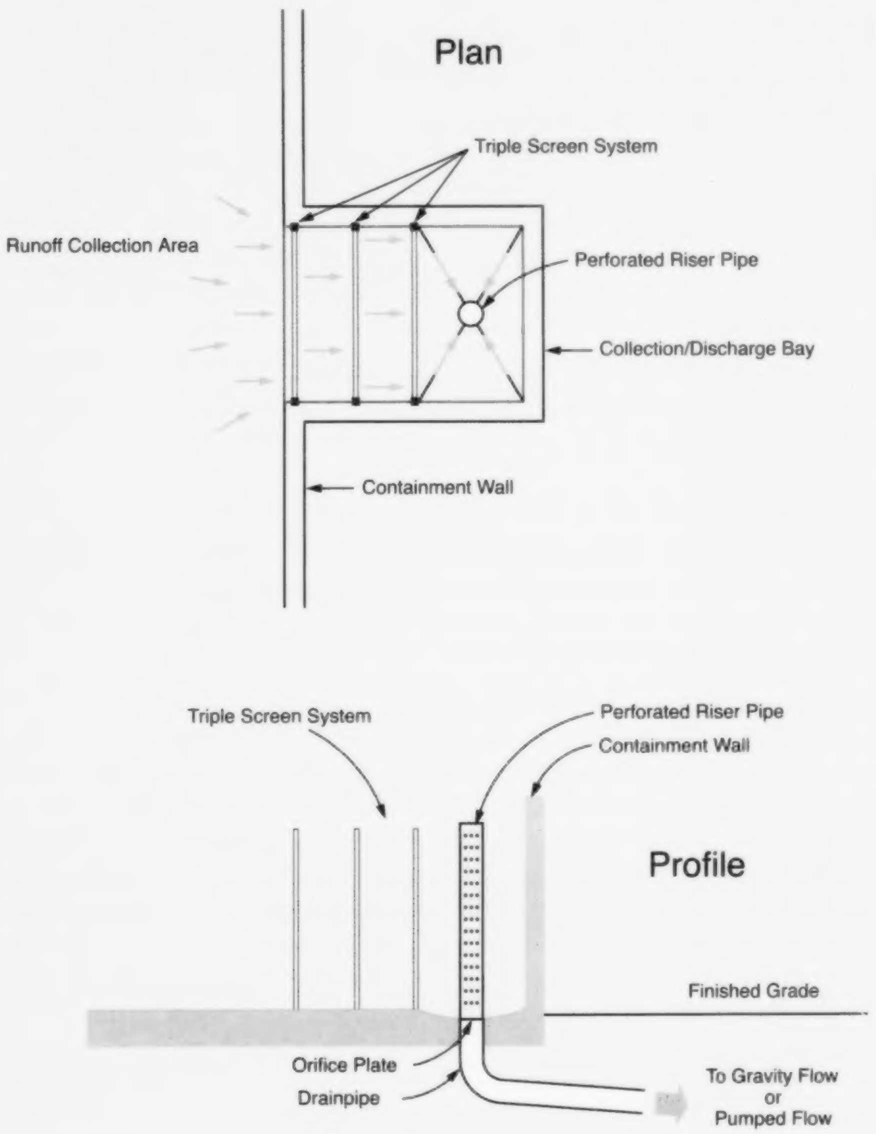
The runoff collection/discharge system has several components. The flow is directed to one common collection point. Prior to being discharged from the runoff area, the runoff passes through a series of screens to remove solids and floatables. An orifice situated at the bottom end of a perforated riser pipe controls the rate of discharge from the runoff collection area to an adjacent below-grade sump. The runoff collection/discharge system will vary depending on whether an integrated or external storage/settling basin configuration is utilized. The following outlines the runoff collection/discharge system being proposed for an integrated and external storage/settling basin configuration.

3.4.1 Integrated Storage/Settling Basin Collection/Discharge System

The integrated storage/settling basin runoff collection/discharge system is outlined in Figure 3.3A. The runoff collection/discharge system has the following primary components which serve the following functions:

- Collection/discharge bay—separates collection point that captures all of the runoff generated from the runoff collection area and discharges it to the sump
- Screens—remove coarse solids and floating material from the runoff
- Drainpipe—directs flow to a below-grade sump
- Orifice—controls the rate of discharge of the runoff from the runoff storage/settling basin
- Perforated riser pipe—provides additional level of screening
- Sump—acts as a common collection point before runoff moves to infiltration area

Figure 3.3A
Integrated storage/settling basin collection/discharge system layout



The following descriptions provide the design criteria to be used to develop the integrated storage/settling basin runoff collection/discharge system components.

Collection/Discharge Bay

In an integrated storage/settling basin configuration, runoff flows by gravity to a common low point and collects in an area referred to as the collection/discharge bay.

Configuration of Collection/Discharge Bay The collection/discharge bay will be constructed outside of the runoff collection area and incorporated into the containment wall, as presented in Figure 3.3A. The collection/discharge bay extends to the full height of the containment wall. The collection/discharge bay has a width of 1.0 to 2.0 m (3.3 to 6.6 ft) to allow for easy access for cleaning. The floor of the containment bay will be flat across the front end of the bay where the screens are located. The perforated pipe will be located in the centre of the bay area, downslope of the screens. The bay area floor will slope down to the perforated pipe on all four sides.

Material The collection/discharge bay containment wall and floor will be constructed using reinforced concrete.

Screens

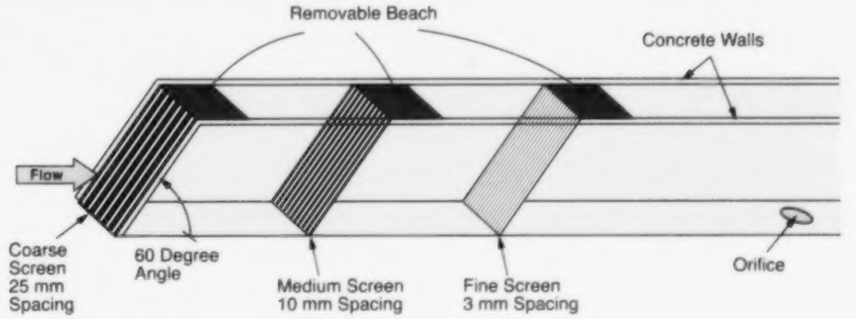
Screens will be incorporated into the opening width of the collection/discharge bay to reduce the potential for clogging of downstream components of the VFS system. Solids contained in the runoff collection area runoff will be removed by the screens before entering the collection/discharge bay.

Configuration of Screens A triple screen system is recommended because it progressively provides a finer level of screening as the runoff passes through the collection/discharge bay. Figure 3.3A illustrates the design of a triple vertical screen system for the integrated storage/settling basin. The screens will be situated at the inflow end of the collection bay, contained in a frame, and placed in c-channel slots attached to the face of the collection/discharge bay. A handle would be placed along the top edge of the frame to facilitate easy removal of screenings. Removing the screens allows direct access to the collection/discharge bay area and discharge orifice. Screens will be placed 0.5 m (1.6 ft) apart. Screens may also be installed on a 60-degree angle above the horizontal (see Figure 3.3B) with a small beach at the top. With this arrangement, the face of each screen can be maintained with a common rake to allow for cleaning. The small beach allows for a location for piling up accumulated solids so that they do not drop into the next screen area. The screens will extend the full height of the containment wall (top of spillway wall height). The following outlines the screen opening sizes for each of the three screens:

1. Coarse—vertical spacing of approximately 25 mm (1 in.)
2. Medium—vertical spacing of approximately 10 mm (3/8 in.)
3. Fine—vertical spacing of approximately 3.1 mm (1/8 in.)

Figure 3.3B

Triple angled screen system



Material The screens may be constructed from a variety of materials including wood, galvanized metal, or other suitable materials. The material must be able to withstand the environmental conditions found in runoff. For example, the bars may be constructed of 50 mm by 25 mm (2 in. by 1 in.) timber in a solid frame, or fabricated out of standard 50 mm wide by 4.5 mm thick (2 in. wide by 3/16 in. thick) flat stock galvanized steel.

Drainpipe/Orifice Plate

A drainpipe, along with an orifice plate, will be installed to control the rate of discharge and direct the flow to the sump prior to being conveyed to the infiltration area.

Sizing of Drainpipe/Orifice Plate The drainpipe and orifice plate will be sized to accommodate the required discharge rate from the storage/settling basin. The minimum drainpipe size and orifice opening will depend on the storage level that is accommodated in the storage/settling basin, and will correspond to the following:

- conservative maximum storage volume (25-year/24-hour rainfall volume)—size of pipe/orifice plate must be able to transfer entire storage volume in a minimum 4 to 10-hour drain period
- less than conservative maximum storage volume, but at least minimum storage volume (generated by 25-year/5-minute storm event over a 15-minute period)—size of pipe/orifice plate must be able to transfer routed peak discharge rate associated with 25-year/24-hour storm event

The drainpipe size may be increased up to two times the discharge rate from the storage basin to accommodate future expansion. The drainpipe should be sized to match a standard pipe size. The orifice plate will be integrated into the inflow end of the drainpipe and utilized to generate the desired discharge flow rate as specified above.

Perforated Riser Pipe A perforated riser pipe will be placed ahead of the orifice plate so that all flow passes through the openings in the riser pipe. The riser pipe primarily functions as a screen. The perforated riser pipe will be the same size as the drainpipe to simplify the connection. Check flow rate through the holes or slots in the perforated pipe to ensure that this estimate of flow rate is greater than that of the orifice. The area of the perforated riser pipe openings must be at least 25 per cent greater than that of the orifice plate opening at maximum head. The additional area of the riser pipe openings will compensate for potential clogging of the riser pipe.

Type of Pipe There are many types of piping suitable for moving wastewater. PVC piping is an appropriate pipe type that is readily available.

Sump

Runoff discharged through the drainpipe outlet from the collection/discharge bay will be directed into a sump.

Configuration of Sump The sump will be installed beside the collection/discharge bay and will be constructed below grade to facilitate year-round operation. The sump's primary function is to provide sufficient height to support the transfer mechanism being considered for the VFS system—a siphon (gravity flow transfer mechanism) or a pump (pumped flow transfer mechanism). The sump size will depend on the size and space requirements of the siphon/pump. Consult siphon and pump manufacturers to establish an appropriate sump size.

Type of Sump There are several different types of pre-fabricated sumps, composed of various materials (concrete, metal, plastic, fibreglass, etc.), that can be used. A pre-fabricated concrete manhole box may also be considered because of its durability, versatility, and access capabilities. An access hatch must be provided to the sump that can be locked to restrict access to the sump.

3.4.2 Integrated Storage/Settling Basin with Direct Discharge to Infiltration Area

An alternate discharge system design involves an integrated storage/settling basin that is able to directly discharge to an infiltration area within 20 m (65.6 ft) of the discharge location. The drainpipe will be placed into the base of the containment wall, and runoff is discharged directly to an adjacent conveyance channel that flows via gravity to the distribution channel at the top end of the infiltration area. The use of this design means that a sump is not necessary.

3.4.3 External Settling/Storage Basin Collection/Discharge System

In an external storage/settling basin design, the runoff that is collected is transferred to the storage/settling basin first. The runoff collection area directs flow (via gravity) to a common low point where the runoff is transferred to the external storage/settling basin. Runoff can be transferred through a pipe or conveyance channel system to the external storage. In all cases the transfer system must be designed to carry the peak discharge flow from the runoff collection area for a 25-year/5-minute duration storm event.
The runoff collection/discharge system has the following primary components that serve the following functions:

- Screens—remove coarse material from the runoff
- Drainpipe—directs flow to a below-grade sump
- Orifice—controls the rate of discharge of the runoff from the external storage/settling basin
- Sump—acts as a common collection point prior to conveyance of runoff to infiltration area

The following descriptions provide the design criteria to be used to develop the external storage/settling basin runoff collection/discharge system components.

Screens

Only a coarse screen, e.g., wood picket fence, should be installed at the runoff exit point of the collection area to prevent coarse materials from entering the external settling/storage basin.

Drainpipe/Orifice Plate The drainpipe is located at the discharge elevation at the same height as the minimum 1 m (3.3 ft) dead storage level of the storage basin. An orifice plate is placed ahead of the discharge pipe to control the rate of discharge from the storage basin to the sump. The drainpipe conveys runoff stored in the storage basin to the sump.

Sizing of Drainpipe/Orifice Plate The drainpipe/orifice plate will be sized to accommodate the required discharge rate from the runoff storage/settling basin. The minimum pipe size/orifice opening will depend on the storage level that is accommodated in the settling basin and will correspond to the following:

- conservative maximum storage volume generated by a 25-year/24-hour storm event—size of pipe/orifice opening/pump must be able to transfer entire storage volume in a 4 to 10-hour drain period
- less than conservative maximum storage volume but at least volume associated with peak discharge rate of a 25-year/5-minute storm event over a 15-minute period—size of pipe/orifice opening/pump must be able to transfer routed peak discharge rate at all times for 25-year/24-hour storm event

The drainpipe size may be increased up to two times the discharge rate from the storage basin to accommodate future expansion. The drainpipe should be sized to match a standard pipe size. The orifice will be integrated into the inflow end of the drainpipe and utilized to generate the desired discharge flow rate specified above.

Type of Pipe The type of pipe will be the same as that used for an integrated storage/settling basin collection/discharge system.

Sump

Runoff discharged through the drainpipe outlet from the external storage/settling basin will be directed into a sump.

Configuration of Sump The sump will be installed directly adjacent to the external storage/settling basin and will be constructed below grade to facilitate year-round operation. The sump characteristics will be the same as that used in the integrated storage/settling basin.

Type of Sump The type of sump will be the same as that used in the integrated storage/settling basin.

Note: In some cases an external concrete storage may already exist on the farm. Provided that the existing storage has capacity to contain either a 25-year/24-hour storm event or a 25-year/5-minute storm event over a 15-minute period, the storage may be used as a sump to support the pump or gravity flow mechanism. The storage tank must be situated below ground to facilitate year-round operation. The tank must be adequate in size to accommodate the settled solids, and access to the tank is required to remove the settled solids on a regular basis.

3.4.4 Calculating Orifice Size Based on Orifice Discharge Capacity

The following section describes the process to be followed in establishing an appropriate orifice opening size that will accommodate a specific discharge rate. Equation 3.7 outlines the variables, units, and mathematical relationship to establish the orifice discharge capacity.

Equation 3.7

Orifice discharge capacity

$$Q = (C)(A)(2gh)^{0.5}$$

Where: Q = orifice discharge capacity (m^3/s)
C = orifice constant (0.61) varies by type of orifice, value considered conservative
A = orifice area (m^2)
g = acceleration due to gravity 9.8 m/s^2
h = head on orifice (m)

If the equation is rearranged to solve for the orifice area (A) then:

$$A = Q/[(C)(2gh)^{0.5}]$$

The following equation is for the area of a circle (the orifice opening):

$$A = \pi D^2/4$$

Rearranging the equation to solve for the diameter (D) of the orifice:

$$D = (4 \times A/\pi)^{0.5}$$

For example, the orifice area A required to discharge the conservative maximum runoff volume from the integrated storage/settling basin over a 4-hour period with a target discharge capacity of 4.80×10^{-3} m^3/s *(0.17* ft^3/s*), an orifice constant of 0.61 (varies by type of orifice, value conservative), gravity at 9.8* m/s^2 *(32.2* ft/s^2*), and a head of 0.21 m (0.69 ft) is equal to* $4.80 \times 10^{-3}\ m^3/s/[(0.61)(2 \times 9.8\ m/s^2 \times 0.21\ m)^{0.5}] = 3.86 \times 10^{-3}\ m^2$ *(0.013* ft^2*). The area of the orifice is equal to 38.6* cm^2 *(6.18* in^2*). Solving for the diameter D of an orifice with an area A of* $3.86 \times 10^{-3}\ m^2$ *is equal to the square root of* $(4 \times 3.86 \times 10^{-3}\ m^2/\pi)] = 7 \times 10^{-2}$ *m (2.77 in.).*

If the target discharge capacity of $1.9 \times 10^{-3}\ m^3/s$ *(0.07* ft^3/s*) was used to determine the orifice diameter required to discharge the conservative maximum runoff volume from the integrated storage/settling basin over a 10-hour period the result would be as follows: an orifice constant of 0.61 (varies by type of orifice, value conservative), gravity at 9.8* m/s^2 *(32.2* ft/s^2*), and a head of 0.21 m (0.69 ft) is equal to* $1.9 \times 10^{-3}\ m^3/s/[(0.61)\ (2 \times 9.8\ m/s^2 \times 0.21\ m)^{0.5}] = 1.54 \times 10^{-3}\ m^2$ *(0.017* ft^2*). The area of the orifice is equal to 15.4* cm^2 *(2.4* in^2*). Solving for the diameter of an orifice with an area of* $1.54 \times 10^{-3}\ m^2$ *(0.017* ft^2*) is equal to the square root of* $(4 \times 1.54 \times 10^{-3}\ m^2/\pi) = 4.4 \times 10^{-2}$ *m (1.7 in.).*

Table 3.1 lists the orifice diameters and areas for a variety of discharge rates for a range of head values.

3.4.5 Perforated Riser Pipe Design

A perforated riser pipe is placed ahead of the orifice plate so that all flow passes through the openings in the riser pipe. The riser pipe primarily functions as a screen. The perforated riser pipe will be the same size as the drainpipe to simplify the connection. Flow rate through the holes or slots in the perforated pipe should be checked to ensure that this estimate of flow rate exceeds that of the orifice. The area of the perforated riser pipe openings must be at least 25 per cent greater than that of the orifice plate opening at maximum head. The additional area of the riser pipe openings will compensate for potential clogging of the riser pipe.

The minimum opening in the riser pipe is determined by using the orifice discharge equation below.

$$Q = (C)(A)(2gh)^{0.5}$$

If the equation is rearranged to solve for the minimum opening area (A) in the riser pipe then:

$$A = Q/[(C)(2gh)^{0.5}]$$

The area of the perforated openings in the riser pipe must be at least 25 per cent greater than that of the orifice plate opening; thus, minimum riser pipe opening area is A x 1.25.

For example, the minimum riser pipe opening area for a discharge rate (Q) of 4.8×10^{-3} *m*^{3}*/s (0.17 ft*^{3}*/s) and a maximum head (h) of 0.7 m (2.3 ft) is equal to* 4.8×10^{-3} *m*^{3}*/s/[(0.61)(2 x 9.81 x 0.7)*$^{0.5}$*] =* 2.1×10^{-3} *m*^{2} *(0.023 ft*^{2}*). Increasing the opening area by 25% results in* 2.1×10^{-3} *m*^{2} *x 1.25 =* 2.63×10^{-3} *m*^{2} *= 26.3 cm*^{2} *(0.028 ft*^{2}*) minimum riser pipe opening area. Using 2 x 2 cm (0.75 in. x 0.75 in.) slots will result in 26.3 cm*^{2}*/4 cm*^{2} *= 6.6 or 7 slots in the 0.7 m (2.3 ft) height of riser pipe above the orifice plate.*

3.5 Conveyance System

The conveyance system is responsible for transferring the runoff from the collection/discharge system to the distribution system.

Table 3.1 Orifice discharge capacity table

Orifice Diameter	**Orifice Area**	**Discharge Capacity at Specific Head**			
		Head (m)			
		0.05	**0.1**	**0.2**	**0.3**
(m)	**(m^2)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**
(in.)	***(ft^2)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***
0.01	7.85E-05	4.74E-05	6.70E-05	9.48E-05	1.16E-04
0.39	*0.00*	*1.10*	*1.55*	*2.20*	*2.69*
0.02	3.14E-04	1.90E-04	2.68E-04	3.79E-04	4.64E-04
0.79	*0.00*	*4.39*	*6.21*	*8.79*	*10.76*
0.03	7.07E-04	4.27E-04	6.03E-04	8.53E-04	1.05E-03
1.18	*0.01*	*9.88*	*13.98*	*19.77*	*24.21*
0.04	1.26E-03	7.58E-04	1.07E-03	1.52E-03	1.86E-03
1.57	*0.01*	*17.57*	*24.85*	*35.14*	*43.04*
0.05	1.96E-03	1.19E-03	1.68E-03	2.37E-03	2.90E-03
1.97	*0.02*	*27.46*	*38.83*	*54.91*	*67.25*
0.06	2.83E-03	1.71E-03	2.41E-03	3.41E-03	4.18E-03
2.36	*0.03*	*39.54*	*55.91*	*79.07*	*96.84*
0.07	3.85E-03	2.32E-03	3.28E-03	4.65E-03	5.69E-03
2.76	*0.04*	*53.81*	*76.10*	*107.63*	*131.82*
0.08	5.02E-03	3.03E-03	4.29E-03	6.07E-03	7.43E-03
3.15	*0.05*	*70.29*	*99.40*	*140.57*	*172.17*
0.09	6.36E-03	3.84E-03	5.43E-03	7.68E-03	9.41E-03
3.54	*0.07*	*88.96*	*125.8*	*177.91*	*217.90*
0.10	7.85E-03	4.74E-03	6.70E-03	9.48E-03	0.01
3.94	*0.08*	*109.82*	*155.31*	*219.65*	*269.01*
0.11	9.50E-03	5.74E-03	8.11E-03	0.01	0.01
4.33	*0.10*	*132.89*	*187.93*	*265.77*	*325.51*
0.12	0.01	6.83E-03	9.65E-03	0.01	0.02
4.72	*0.12*	*158.15*	*223.65*	*316.29*	*387.38*
0.13	0.01	0.01	0.01	0.02	0.02
5.12	*0.14*	*185.6*	*262.48*	*371.21*	*454.63*
0.14	0.02	0.01	0.01	0.02	0.02
5.51	*0.17*	*215.26*	*304.42*	*430.51*	*527.27*
0.15	0.02	0.01	0.02	0.02	0.03
5.91	*0.19*	*247.1*	*349.46*	*494.21*	*605.28*
0.16	0.02	0.01	0.02	0.02	0.03
6.30	*0.22*	*281.15*	*397.61*	*562.3*	*688.67*
0.17	0.02	0.01	0.02	0.03	0.03
6.69	*0.24*	*317.39*	*448.86*	*634.78*	*777.45*
0.18	0.03	0.02	0.02	0.03	0.04
7.09	*0.27*	*355.83*	*503.22*	*711.66*	*871.60*
0.19	0.03	0.02	0.02	0.03	0.04
7.48	*0.31*	*396.46*	*560.69*	*792.93*	*971.14*
0.20	0.03	0.02	0.03	0.04	0.05
7.87	*0.34*	*439.3*	*621.26*	*878.59*	*1,076.05*
0.21	0.03	0.02	0.03	0.04	0.05
8.27	*0.37*	*484.32*	*684.94*	*968.65*	*1,186.35*
0.22	0.04	0.02	0.03	0.05	0.06
8.66	*0.41*	*531.55*	*751.72*	*1,063.10*	*1,302.02*
0.23	0.04	0.03	0.04	0.05	0.06
9.06	*0.45*	*580.97*	*821.61*	*1,161.94*	*1,423.08*
0.24	0.05	0.03	0.04	0.05	0.07
9.45	*0.49*	*632.59*	*894.61*	*1,265.17*	*1,549.51*

Using equation Q = (C) (A) $(2gh)^{0.5}$, with the following variables: Q = Orifice discharge, C = Orifice constant = 0.61 (varies by type of orifice, value considered conservative), A = Orifice Area m^2, g = 9.8 m/s^2, h = Head of Orifice m

Orifice Diameter	**Orifice Area**	**Discharge Capacity at Specific Head**			
		Head (m)			
		0.4	**0.5**	**0.6**	**0.7**
(m)	**(m^2)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**
(in.)	***(ft^2)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***
0.01	7.85E-05	1.34E-04	1.50E-04	1.64E-04	1.77E-04
0.39	*0.00*	*3.11*	*3.47*	*3.80*	*4.11*
0.02	3.14E-04	5.36E-04	6.00E-04	6.57E-04	7.09E-04
0.79	*0.00*	*12.43*	*13.89*	*15.22*	*16.44*
0.03	7.07E-04	1.21E-03	1.35E-03	1.48E-03	1.60E-03
1.18	*0.01*	*27.96*	*31.26*	*34.24*	*36.98*
0.04	1.26E-03	2.15E-03	2.40E-03	2.63E-03	2.84E-03
1.57	*0.01*	*49.70*	*55.57*	*60.87*	*65.75*
0.05	1.96E-03	3.35E-03	3.75E-03	4.11E-03	4.43E-03
1.97	*0.02*	*77.66*	*86.82*	*95.11*	*102.73*
0.06	2.83E-03	4.83E-03	5.40E-03	5.91E-03	6.39E-03
2.36	*0.03*	*111.83*	*125.03*	*136.96*	*147.93*
0.07	3.85E-03	6.57E-03	7.35E-03	8.05E-03	8.69E-03
2.76	*0.04*	*152.21*	*170.17*	*186.42*	*201.35*
0.08	5.02E-03	8.58E-03	9.59E-03	0.01	0.01
3.15	*0.05*	*198.80*	*222.27*	*243.48*	*262.99*
0.09	6.36E-03	0.01	0.01	0.01	0.01
3.54	*0.07*	*251.61*	*281.31*	*308.16*	*332.85*
0.10	7.85E-03	0.01	0.01	0.02	0.02
3.94	*0.08*	*310.63*	*347.29*	*380.44*	*410.92*
0.11	9.50E-03	0.02	0.02	0.02	0.02
4.33	*0.10*	*375.86*	*420.23*	*460.33*	*497.22*
0.12	0.01	0.02	0.02	0.02	0.03
4.72	*0.12*	*447.31*	*500.10*	*547.84*	*591.73*
0.13	0.01	0.02	0.03	0.03	0.03
5.12	*0.14*	*524.96*	*586.93*	*642.95*	*694.46*
0.14	0.02	0.03	0.03	0.03	0.03
5.51	*0.17*	*608.83*	*680.70*	*745.67*	*805.41*
0.15	0.02	0.03	0.03	0.04	0.04
5.91	*0.19*	*698.92*	*781.41*	*855.99*	*924.58*
0.16	0.02	0.03	0.04	0.04	0.05
6.30	*0.22*	*795.21*	*889.07*	*973.93*	*1,051.97*
0.17	0.02	0.04	0.04	0.05	0.05
6.69	*0.24*	*897.72*	*1003.68*	*1,099.48*	*1,187.57*
0.18	0.03	0.04	0.05	0.05	0.06
7.09	*0.27*	*1,006.44*	*1125.23*	*1,232.63*	*1,331.39*
0.19	0.03	0.05	0.05	0.06	0.06
7.48	*0.31*	*1,121.37*	*1253.73*	*1,373.39*	*1,483.44*
0.20	0.03	0.05	0.06	0.07	0.07
7.87	*0.34*	*1,242.52*	*1389.18*	*1,521.77*	*1,643.70*
0.21	0.03	0.06	0.07	0.07	0.08
8.27	*0.37*	*1,369.87*	*1531.57*	*1,677.75*	*1,812.17*
0.22	0.04	0.06	0.07	0.08	0.09
8.66	*0.41*	*1,503.45*	*1680.90*	*1,841.34*	*1,988.87*
0.23	0.04	0.07	0.08	0.09	0.09
9.06	*0.45*	*1,643.23*	*1837.19*	*2,012.54*	*2,173.79*
0.24	0.05	0.08	0.09	0.09	0.10
9.45	*0.49*	*1,789.22*	*2000.41*	*2,191.34*	*2,366.92*

Using equation $Q = (C)(A)(2gh)^{0.5}$, with the following variables: Q = Orifice discharge, C = Orifice constant = 0.61 (varies by type of orifice, value considered conservative), A = Orifice Area m^2, $g = 9.8\ m/s^2$, h = Head of Orifice m

Orifice Diameter	Orifice Area	Discharge Capacity at Specific Head			
		Head (m)			
		0.8	0.9	1	1.1
(m)	(m^2)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
(in.)	*(ft^2)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
0.01	7.85E-05	1.90E-04	2.01E-04	2.12E-04	2.22E-04
0.39	*0.00*	*4.39*	*4.66*	*4.91*	*5.15*
0.02	3.14E-04	7.58E-04	8.04E-04	8.48E-04	8.89E-04
0.79	*0.00*	*17.57*	*18.64*	*19.65*	*20.60*
0.03	7.07E-04	1.71E-03	1.81E-03	1.91E-03	2.00E-03
1.18	*0.01*	*39.54*	*41.93*	*44.20*	*46.36*
0.04	1.26E-03	3.03E-03	3.22E-03	3.39E-03	3.56E-03
1.57	*0.01*	*70.29*	*74.55*	*78.58*	*82.42*
0.05	1.96E-03	4.74E-03	5.03E-03	5.30E-03	5.56E-03
1.97	*0.02*	*109.82*	*116.49*	*122.79*	*128.78*
0.06	2.83E-03	6.83E-03	7.24E-03	7.63E-03	8.00E-03
2.36	*0.03*	*158.15*	*167.74*	*176.81*	*185.44*
0.07	3.85E-03	9.29E-03	9.85E-03	0.01	0.01
2.76	*0.04*	*215.26*	*228.31*	*240.66*	*252.41*
0.08	5.02E-03	0.01	0.01	0.01	0.01
3.15	*0.05*	*281.15*	*298.20*	*314.33*	*329.68*
0.09	6.36E-03	0.02	0.02	0.02	0.02
3.54	*0.07*	*355.83*	*377.41*	*397.83*	*417.25*
0.10	7.85E-03	0.02	0.02	0.02	0.02
3.94	*0.08*	*439.30*	*465.94*	*491.15*	*515.12*
0.11	9.50E-03	0.02	0.02	0.03	0.03
4.33	*0.10*	*531.55*	*563.79*	*594.29*	*623.30*
0.12	0.01	0.03	0.03	0.03	0.03
4.72	*0.12*	*632.59*	*670.96*	*707.25*	*741.77*
0.13	0.01	0.03	0.03	0.04	0.04
5.12	*0.14*	*742.41*	*787.45*	*830.04*	*870.55*
0.14	0.02	0.04	0.04	0.04	0.04
5.51	*0.17*	*861.02*	*913.25*	*962.65*	*1,009.64*
0.15	0.02	0.04	0.05	0.05	0.05
5.91	*0.19*	*988.42*	*1,048.37*	*1,105.08*	*1,159.02*
0.16	0.02	0.05	0.05	0.05	0.06
6.30	*0.22*	*1,124.60*	*1,192.82*	*1,257.34*	*1,318.71*
0.17	0.02	0.05	0.06	0.06	0.06
6.69	*0.24*	*1,269.57*	*1,346.58*	*1,419.42*	*1,488.70*
0.18	0.03	0.06	0.07	0.07	0.07
7.09	*0.27*	*1,423.32*	*1,509.66*	*1,591.32*	*1,668.99*
0.19	0.03	0.07	0.07	0.08	0.08
7.48	*0.31*	*1,585.86*	*1,682.06*	*1,773.04*	*1,859.58*
0.20	0.03	0.08	0.08	0.08	0.09
7.87	*0.34*	*1,757.18*	*1,863.78*	*1,964.59*	*2,060.48*
0.21	0.03	0.08	0.09	0.09	0.10
8.27	*0.37*	*1,937.30*	*2,054.81*	*2,165.96*	*2,271.68*
0.22	0.04	0.09	0.10	0.10	0.11
8.66	*0.41*	*2,126.19*	*2,255.17*	*2,377.16*	*2,493.18*
0.23	0.04	0.10	0.11	0.11	0.12
9.06	*0.45*	*2,323.88*	*2,464.84*	*2,598.17*	*2,724.99*
0.24	0.05	0.11	0.12	0.12	0.13
9.45	*0.49*	*2,530.35*	*2,683.84*	*2,829.01*	*2,967.09*

Using equation $Q = (C)(A)(2gh)^{0.5}$, with the following variables: Q = Orifice discharge, C = Orifice constant = 0.61 (varies by type of orifice, value considered conservative), A = Orifice Area m^2, $g = 9.8\ m/s^2$, h = Head of Orifice m

Orifice Diameter	**Orifice Area**	**Discharge Capacity at Specific Head**			
		Head (m)			
		1.2	**1.3**	**1.4**	**1.5**
(m)	**(m^2)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**
(in.)	***(ft^2)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***
0.01	7.85E-05	2.32E-04	2.42E-04	2.51E-04	2.60E-04
0.39	*0.00*	*5.38*	*5.60*	*5.81*	*6.02*
0.02	3.14E-04	9.29E-04	9.67E-04	1.00E-03	1.04E-03
0.79	*0.00*	*21.52*	*22.40*	*23.25*	*24.06*
0.03	7.07E-04	2.09E-03	2.18E-03	2.26E-03	2.34E-03
1.18	*0.01*	*48.42*	*50.40*	*52.30*	*54.14*
0.04	1.26E-03	3.72E-03	3.87E-03	4.01E-03	4.15E-03
1.57	*0.01*	*86.08*	*89.60*	*92.98*	*96.24*
0.05	1.96E-03	5.81E-03	6.04E-03	6.27E-03	6.49E-03
1.97	*0.02*	*134.51*	*140.00*	*145.28*	*150.38*
0.06	2.83E-03	8.36E-03	8.70E-03	9.03E-03	9.35E-03
2.36	*0.03*	*193.69*	*201.60*	*209.21*	*216.55*
0.07	3.85E-03	0.01	0.01	0.01	0.01
2.76	*0.04*	*263.63*	*274.40*	*284.76*	*294.75*
0.08	5.02E-03	0.01	0.02	0.02	0.02
3.15	*0.05*	*344.34*	*358.40*	*371.93*	*384.98*
0.09	6.36E-03	0.02	0.02	0.02	0.02
3.54	*0.07*	*435.80*	*453.60*	*470.72*	*487.24*
0.10	7.85E-03	0.02	0.02	0.03	0.03
3.94	*0.08*	*538.03*	*559.99*	*581.13*	*601.53*
0.11	9.50E-03	0.03	0.03	0.03	0.03
4.33	*0.10*	*651.01*	*677.59*	*703.17*	*727.85*
0.12	0.01	0.03	0.03	0.04	0.04
4.72	*0.12*	*774.76*	*806.39*	*836.83*	*866.20*
0.13	0.01	0.04	0.04	0.04	0.04
5.12	*0.14*	*909.26*	*946.39*	*982.12*	*1,016.59*
0.14	0.02	0.05	0.05	0.05	0.05
5.51	*0.17*	*1,054.53*	*1,097.59*	*1,139.02*	*1,179.00*
0.15	0.02	0.05	0.05	0.06	0.06
5.91	*0.19*	*1,210.56*	*1,259.99*	*1,307.55*	*1,353.44*
0.16	0.02	0.06	0.06	0.06	0.07
6.30	*0.22*	*1,377.35*	*1,433.59*	*1,487.70*	*1,539.92*
0.17	0.02	0.07	0.07	0.07	0.08
6.69	*0.24*	*1,554.89*	*1,618.38*	*1,679.48*	*1,738.42*
0.18	0.03	0.08	0.08	0.08	0.08
7.09	*0.27*	*1,743.20*	*1,814.38*	*1,882.87*	*1,948.96*
0.19	0.03	0.08	0.09	0.09	0.09
7.48	*0.31*	*1,942.27*	*2,021.58*	*2,097.89*	*2,171.53*
0.20	0.03	0.09	0.10	0.10	0.10
7.87	*0.34*	*2,152.10*	*2,239.98*	*2,324.54*	*2,406.12*
0.21	0.03	0.10	0.11	0.11	0.11
8.27	*0.37*	*2,372.69*	*2,469.58*	*2,562.80*	*2,652.75*
0.22	0.04	0.11	0.12	0.12	0.13
8.66	*0.41*	*2,604.04*	*2,710.37*	*2,812.69*	*2,911.41*
0.23	0.04	0.12	0.13	0.13	0.14
9.06	*0.45*	*2,846.16*	*2,962.37*	*3,074.20*	*3,182.10*
0.24	0.05	0.13	0.14	0.14	0.15
9.45	*0.49*	*3,099.03*	*3,225.57*	*3,347.33*	*3,464.82*

Using equation $Q = (C)\ (A)\ (2gh)^{0.5}$, with the following variables: Q = Orifice discharge, C = Orifice constant = 0.61 (varies by type of orifice, value considered conservative), A = Orifice Area m^2, g = 9.8 m/s^2, h = Head of Orifice m

Orifice Diameter	Orifice Area	Discharge Capacity at Specific Head			
		Head (m)			
		1.6	1.7	1.8	1.9
(m)	(m^2)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
(in.)	*(ft^2)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
0.01	7.85E-05	2.68E-04	2.76E-04	2.84E-04	2.92E-04
0.39	*0.00*	*6.21*	*6.40*	*6.59*	*6.77*
0.02	3.14E-04	1.07E-03	1.11E-03	1.14E-03	1.17E-03
0.79	*0.00*	*24.85*	*25.62*	*26.36*	*27.08*
0.03	7.07E-04	2.41E-03	2.49E-03	2.56E-03	2.63E-03
1.18	*0.01*	*55.91*	*57.63*	*59.30*	*60.93*
0.04	1.26E-03	4.29E-03	4.42E-03	4.55E-03	4.68E-03
1.57	*0.01*	*99.40*	*102.46*	*105.43*	*108.32*
0.05	1.96E-03	6.70E-03	6.91E-03	7.11E-03	7.31E-03
1.97	*0.02*	*155.31*	*160.09*	*164.74*	*169.25*
0.06	2.83E-03	9.65E-03	9.95E-03	1.02E-02	1.05E-02
2.36	*0.03*	*223.65*	*230.54*	*237.22*	*243.72*
0.07	3.85E-03	0.01	0.01	0.01	0.01
2.76	*0.04*	*304.42*	*313.79*	*322.88*	*331.73*
0.08	5.02E-03	0.02	0.02	0.02	0.02
3.15	*0.05*	*397.61*	*409.84*	*421.72*	*433.28*
0.09	6.36E-03	0.02	0.02	0.02	0.02
3.54	*0.07*	*503.22*	*518.71*	*533.74*	*548.37*
0.10	7.85E-03	0.03	0.03	0.03	0.03
3.94	*0.08*	*621.26*	*640.38*	*658.94*	*677.00*
0.11	9.50E-03	0.03	0.03	0.03	0.04
4.33	*0.10*	*751.72*	*774.86*	*797.32*	*819.17*
0.12	0.01	0.04	0.04	0.04	0.04
4.72	*0.12*	*894.61*	*922.15*	*948.88*	*974.88*
0.13	0.01	0.05	0.05	0.05	0.05
5.12	*0.14*	*1,049.93*	*1082.24*	*1113.62*	*1144.13*
0.14	0.02	0.05	0.05	0.06	0.06
5.51	*0.17*	*1,217.67*	*1255.14*	*1291.53*	*1326.92*
0.15	0.02	0.06	0.06	0.06	0.07
5.91	*0.19*	*1,397.83*	*1440.85*	*1482.62*	*1523.25*
0.16	0.02	0.07	0.07	0.07	0.07
6.30	*0.22*	*1,590.42*	*1639.37*	*1686.90*	*1733.12*
0.17	0.02	0.08	0.08	0.08	0.08
6.69	*0.24*	*1,795.44*	*1850.69*	*1904.35*	*1956.53*
0.18	0.03	0.09	0.09	0.09	0.09
7.09	*0.27*	*2,012.88*	*2074.83*	*2134.98*	*2193.48*
0.19	0.03	0.10	0.10	0.10	0.11
7.48	*0.31*	*2,242.74*	*2311.77*	*2378.79*	*2443.97*
0.20	0.03	0.11	0.11	0.11	0.12
7.87	*0.34*	*2,485.03*	*2561.51*	*2635.78*	*2708.00*
0.21	0.03	0.12	0.12	0.13	0.13
8.27	*0.37*	*2,739.75*	*2824.07*	*2905.94*	*2985.57*
0.22	0.04	0.13	0.13	0.14	0.14
8.66	*0.41*	*3,006.89*	*3099.43*	*3189.29*	*3276.68*
0.23	0.04	0.14	0.15	0.15	0.15
9.06	*0.45*	*3,286.46*	*3387.60*	*3485.81*	*3581.33*
0.24	0.05	0.15	0.16	0.16	0.17
9.45	*0.49*	*3,578.45*	*3688.58*	*3795.52*	*3899.52*

Using equation $Q = (C)(A)(2gh)^{0.5}$, with the following variables: Q = Orifice discharge, C = Orifice constant = 0.61 (varies by type of orifice, value considered conservative), A = Orifice Area m^2, g = 9.8 m/s^2, h = Head of Orifice m

Orifice Diameter	Orifice Area	Discharge Capacity at Specific Head		
		Head (m)		
		2	2.1	2.2
(m)	(m^2)	(m^3/s)	(m^3/s)	(m^3/s)
(in.)	*(ft^2)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
0.01	7.85E-05	3.00E-04	3.07E-04	3.14E-04
0.39	*0*	*6.95*	*7.12*	*7.28*
0.02	3.14E-04	1.20E-03	1.23E-03	1.26E-03
0.79	*0*	*27.78*	*28.47*	*29.14*
0.03	7.07E-04	2.70E-03	2.76E-03	2.83E-03
1.18	*0.01*	*62.51*	*64.06*	*65.56*
0.04	1.26E-03	4.80E-03	4.92E-03	5.03E-03
1.57	*0.01*	*111.13*	*113.88*	*116.56*
0.05	1.96E-03	7.50E-03	7.68E-03	7.86E-03
1.97	*0.02*	*173.65*	*177.94*	*182.12*
0.06	2.83E-03	1.08E-02	1.11E-02	1.13E-02
2.36	*0.03*	*250.05*	*256.23*	*262.26*
0.07	3.85E-03	0.01	0.02	0.02
2.76	*0.04*	*340.35*	*348.75*	*356.96*
0.08	5.02E-03	0.02	0.02	0.02
3.15	*0.05*	*444.54*	*455.51*	*466.23*
0.09	6.36E-03	0.02	0.02	0.03
3.54	*0.07*	*562.62*	*576.51*	*590.08*
0.1	7.85E-03	0.03	0.03	0.03
3.94	*0.08*	*694.59*	*711.74*	*728.49*
0.11	9.50E-03	0.04	0.04	0.04
4.33	*0.1*	*840.45*	*861.21*	*881.47*
0.12	0.01	0.04	0.04	0.05
4.72	*0.12*	*1000.21*	*1024.91*	*1049.03*
0.13	0.01	0.05	0.05	0.05
5.12	*0.14*	*1173.85*	*1202.84*	*1231.15*
0.14	0.02	0.06	0.06	0.06
5.51	*0.17*	*1361.39*	*1395.01*	*1427.84*
0.15	0.02	0.07	0.07	0.07
5.91	*0.19*	*1562.82*	*1601.42*	*1639.10*
0.16	0.02	0.08	0.08	0.08
6.3	*0.22*	*1778.15*	*1822.06*	*1864.93*
0.17	0.02	0.09	0.09	0.09
6.69	*0.24*	*2007.36*	*2056.93*	*2105.34*
0.18	0.03	0.10	0.10	0.10
7.09	*0.27*	*2250.47*	*2306.04*	*2360.31*
0.19	0.03	0.11	0.11	0.11
7.48	*0.31*	*2507.46*	*2569.38*	*2629.85*
0.2	0.03	0.12	0.12	0.13
7.87	*0.34*	*2778.35*	*2846.96*	*2913.96*
0.21	0.03	0.13	0.14	0.14
8.27	*0.37*	*3063.13*	*3138.78*	*3212.64*
0.22	0.04	0.15	0.15	0.15
8.66	*0.41*	*3361.81*	*3444.83*	*3525.89*
0.23	0.04	0.16	0.16	0.17
9.06	*0.45*	*3674.37*	*3765.11*	*3853.71*
0.24	0.05	0.17	0.18	0.18
9.45	*0.49*	*4000.83*	*4099.63*	*4196.10*

Using equation $Q = (C)(A)(2gh)^{0.5}$, with the following variables: Q = Orifice discharge, C = Orifice constant = 0.61 (varies by type of orifice, value considered conservative), A = Orifice Area m^2, $g = 9.8\ m/s^2$, h = Head of Orifice m

Orifice Diameter	Orifice Area	Discharge Capacity at Specific Head		
		Head (m)		
		2.3	2.4	2.5
(m)	(m^2)	(m^3/s)	(m^3/s)	(m^3/s)
(in.)	*(ft^2)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
0.01	7.85E-05	3.22E-04	3.28E-04	3.35E-04
0.39	*0*	*7.45*	*7.61*	*7.77*
0.02	3.14E-04	1.29E-03	1.31E-03	1.34E-03
0.79	*0*	*29.79*	*30.44*	*31.06*
0.03	7.07E-04	2.89E-03	2.96E-03	3.02E-03
1.18	*0.01*	*67.04*	*68.48*	*69.89*
0.04	1.26E-03	5.14E-03	5.25E-03	5.36E-03
1.57	*0.01*	*119.18*	*121.74*	*124.25*
0.05	1.96E-03	8.04E-03	8.21E-03	8.38E-03
1.97	*0.02*	*186.22*	*190.22*	*194.14*
0.06	2.83E-03	1.16E-02	1.18E-02	1.21E-02
2.36	*0.03*	*268.15*	*273.92*	*279.57*
0.07	3.85E-03	0.02	0.02	0.02
2.76	*0.04*	*364.98*	*372.83*	*380.52*
0.08	5.02E-03	0.02	0.02	0.02
3.15	*0.05*	*476.71*	*486.97*	*497.01*
0.09	6.36E-03	0.03	0.03	0.03
3.54	*0.07*	*603.34*	*616.32*	*629.02*
0.1	7.85E-03	0.03	0.03	0.03
3.94	*0.08*	*744.86*	*760.88*	*776.57*
0.11	9.50E-03	0.04	0.04	0.04
4.33	*0.1*	*901.28*	*920.67*	*939.65*
0.12	0.01	0.05	0.05	0.05
4.72	*0.12*	*1072.60*	*1095.67*	*1118.27*
0.13	0.01	0.05	0.06	0.06
5.12	*0.14*	*1258.82*	*1285.89*	*1312.41*
0.14	0.02	0.06	0.06	0.07
5.51	*0.17*	*1459.93*	*1491.33*	*1522.08*
0.15	0.02	0.07	0.07	0.08
5.91	*0.19*	*1675.94*	*1711.99*	*1747.29*
0.16	0.02	0.08	0.08	0.09
6.3	*0.22*	*1906.85*	*1947.86*	*1988.03*
0.17	0.02	0.09	0.09	0.10
6.69	*0.24*	*2152.65*	*2198.95*	*2244.30*
0.18	0.03	0.10	0.11	0.11
7.09	*0.27*	*2413.36*	*2465.26*	*2516.10*
0.19	0.03	0.12	0.12	0.12
7.48	*0.31*	*2688.95*	*2746.79*	*2803.43*
0.2	0.03	0.13	0.13	0.13
7.87	*0.34*	*2979.45*	*3043.53*	*3106.29*
0.21	0.03	0.14	0.14	0.15
8.27	*0.37*	*3284.84*	*3355.49*	*3424.69*
0.22	0.04	0.16	0.16	0.16
8.66	*0.41*	*3605.14*	*3682.67*	*3758.61*
0.23	0.04	0.17	0.17	0.18
9.06	*0.45*	*3940.32*	*4025.07*	*4108.07*
0.24	0.05	0.19	0.19	0.19
9.45	*0.49*	*4290.41*	*4382.69*	*4473.06*

Using equation $Q = (C)(A)(2gh)^{0.5}$, with the following variables: Q = Orifice discharge, C = Orifice constant = 0.61 (varies by type of orifice, value considered conservative), A = Orifice Area m^2, $g = 9.8\ m/s^2$, h = Head of Orifice m

3.5.1 Conveyance Mechanism

The two conveyance mechanisms available for the conveyance of runoff from the sump to the infiltration area within the VFS system are:

- gravity flow
- pump

Gravity flow, the preferred and cheaper option, depends upon the grade differential between the runoff collection area or sump and the infiltration area. If sufficient grade differential exists to effectively move runoff via gravity, then this option should be pursued. However, experience in the northeastern United States has shown that a large majority of the systems rely on pumps to convey runoff from the storage/settling basin to the infiltration area. A pump will be required if the runoff will not flow by gravity from the runoff collection area to the infiltration area. More than one pump may be required if the water from the runoff collection area is unable to flow to the external storage/settling basin, particularly if an existing storage facility (such as an elevated tank) is being considered.

3.5.2 Open Channel Conveyance

The preferred conveyance method for the VFS system runoff is via a pipe. Piping is required in most components of the VFS system and serves the dual function of dictating flow rates and routes. The opportunity to utilize an open channel (see Figure 3.4) is limited to farmsteads where there is adequate grade differential to support gravity flow from the storage/settling basin to the infiltration area. An open channel should be considered only when the infiltration area is situated directly adjacent to an integrated storage/settling basin. Runoff from the integrated storage/settling basin is discharged at the base of the containment wall and directed into an open channel. The open channel must be less than 20 m (65.6 ft) in length and discharge into a rock-lined distribution channel at the top end of the infiltration area. The conveyance channel may need to be properly lined to prevent infiltration to ground water. A culvert may be required along the open channel to accommodate crossing by farm equipment, livestock, or people.

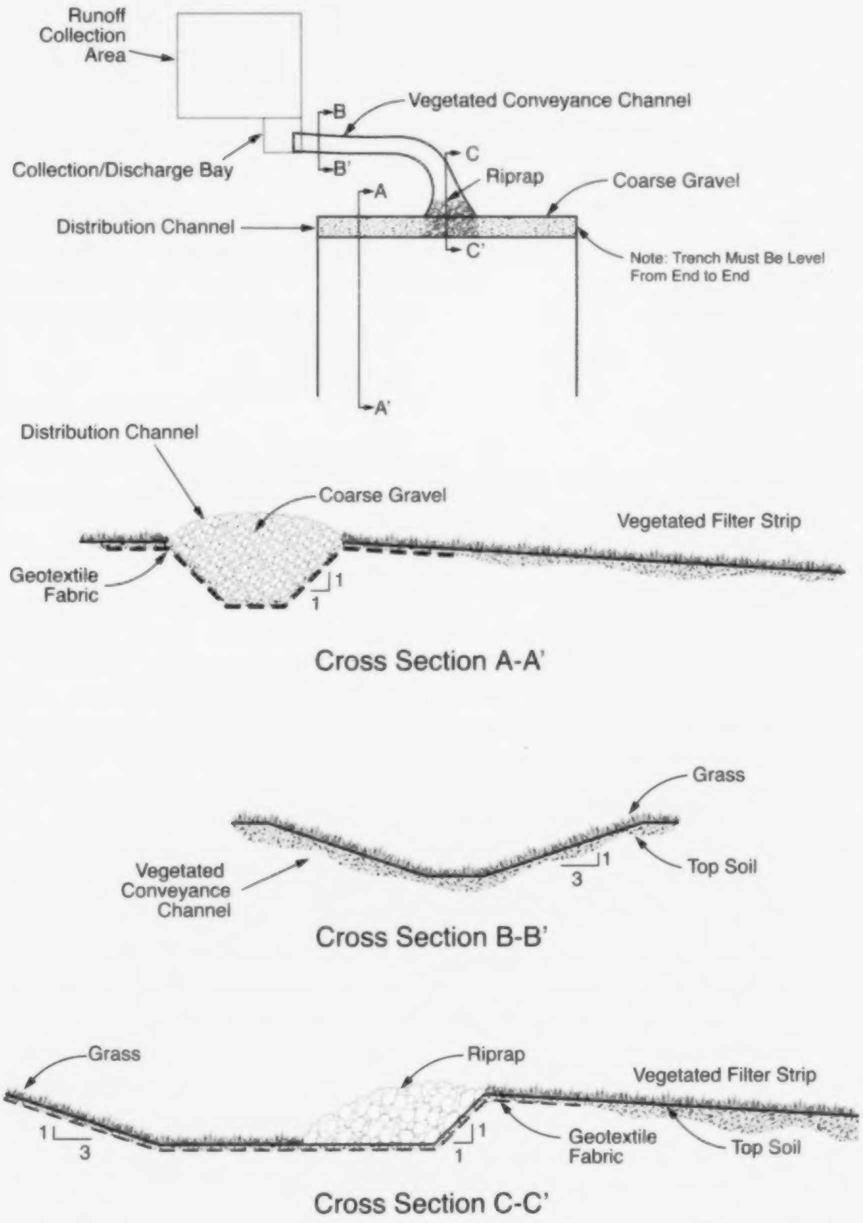
The design, maintenance, and operation considerations associated with the development of an open channel include:

- buildup of solids in the channel
- seasonal impacts, particularly during winter months when the channel may be rendered unusable
- greater maintenance requirements associated with silt removal, vegetation control, and potentially, rodents
- erosion protection measures and energy dissipation requirements associated with channels under severe flows

It is recommended that pipes are used, where possible, as experience with VFS systems in the northeastern United States shows that pipes operate more effectively than open channels.

Figure 3.4

Conveyance and distribution channel



3.5.3 Managing Flow to Conveyance Pipe

In the development of both the internal and external storage/settling basins scenario, discharge from the storage/settling basin is directed to a below-grade sump. The sump is the central collection area for all runoff to be conveyed to the infiltration area. The sump facilitates the creation of pulsed flow, an important characteristic of the flow stream that allows for optimum utilization of the infiltration area. With pulsed flow, a consistent flow of water is generated to the infiltration area when the pump is on, promoting even distribution of the flow. This is a critical aspect that improves the performance and efficiency of the infiltration area.

The runoff from the storage/settling basin will be directed to a sump and discharged to the conveyance pipe/channel by a siphon or pump. The siphon utilizes gravity flow to transfer flow to the conveyance pipe. A pump is required where there is insufficient grade change to accommodate gravity flow. Figure 3.5 illustrates the recommended design of a gravity and pump flow mechanism.

Gravity Flow Mechanism

With the use of gravity flow, pulsed flow to the infiltration area is generated by installing an automatic siphon system in the sump to purge or clear the flow (e.g., Flout™, *www.rissyplastics.com*)[1]. Automatic siphon systems (see Figure 3.5) are activated when a certain elevation of the liquid is reached (high water level). The systems rapidly drain the tank to a low water level. The rate of flow varies based on the drawdown depth. When the low water level is reached, the siphon shuts off and stops the flow of runoff. The siphon repeats the cycle when the water level rises to the set maximum water level in the sump. The diameter of the discharge pipe that exits the sump is 100 mm (4 in.), and is consistent with the conveyance pipe diameter being proposed for gravity flow mechanisms.

There are several operating factors to be incorporated into the design of the sump to accommodate an automatic siphon system. The automatic siphon should shut off approximately 127 mm (5 in.) from the bottom of the sump. An additional 173 mm (7 in.) of dead storage should be provided to accommodate settlement of solids. The turn-on depth should be a minimum of 150 mm (6 in.) below the inlet pipe invert to the sump. The minimum operating depth of the automatic siphon system should be equal to the drawdown depth plus 300 mm (1 ft). The depth of the sump that is selected must accommodate the operating parameters associated with the specific automatic siphon device selected. Similarly, the length of the sump must be greater than the drawdown depth of the dosing unit plus 600 mm (2 ft). The location of the inlet pipe to the sump should be established so that it does not interfere with the operation of the dosing unit. Baffles may be required to deflect inlet pipe flow and control water movement in the sump.

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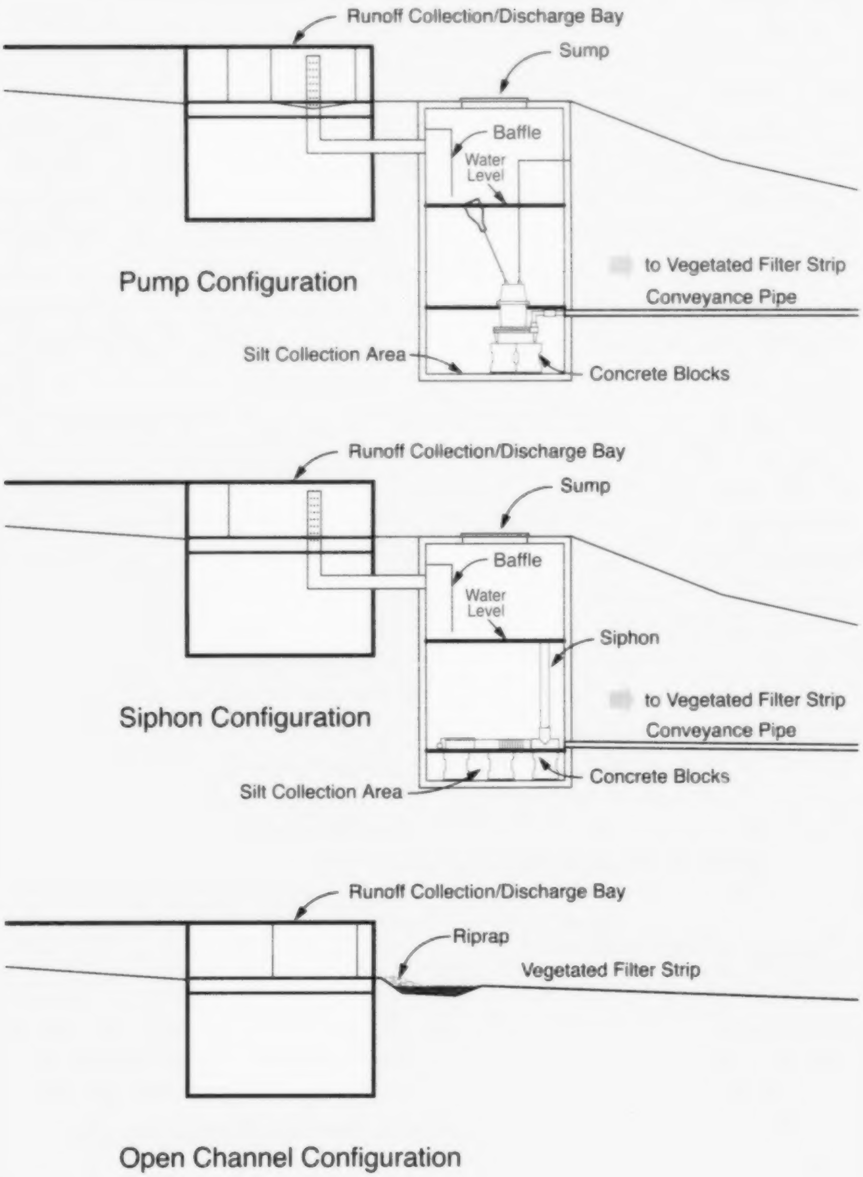
[1] The use of trademarks does not imply endorsement by OMAFRA, MOE, and CH2M HILL Canada Limited.

Figure 3.5
Pump/siphon/channel configuration



Selecting the Appropriate Discharge Rate to the Conveyance Pipe The target discharge rate to the conveyance pipe should be 10 per cent greater than the discharge rate established for the integrated and external storage/settling basin. Calculate an appropriate drawdown depth that corresponds to the required discharge rate to the conveyance pipe. The maximum flow rate for the drawdown depth should be used and matched to the required discharge rate to the conveyance pipe.

Pump and Installation Requirements

A submersible sewage pump (see Figure 3.5) operates using a float switch that triggers the pump to start a discharge cycle at a specified water elevation. The float switch is adjustable so that the drawdown depth and duration of the flow can be modified. The pump should be installed in the sump approximately 300 mm (1 ft) above the bottom of the sump to allow for settlement of solids. The pump can be placed on an elevated platform made of concrete blocks or a series of stacked patio stones. The pump should be placed in a location that is easily accessible from the sump hatch. A power supply will be required to the pump.

Selecting the Appropriate Discharge Rate to the Conveyance Pipe The target discharge rate to the conveyance pipe should be 10 per cent greater than the discharge rate established for the integrated and external storage/settling basin. The discharge rate of a pump will vary according to the capacity of the pump motor (measured in horsepower) at various head differentials (change in grade from inflow point in sump to discharge elevation at distribution pipe merger). An appropriate pump size and corresponding discharge rate will need to be established. Contact a pump manufacturer to help determine (1) an appropriate pump size, (2) the appropriate operating parameters to meet the site-specific design requirements of the conveyance system and (3) the pump curves for the appropriate pump selected. The pump rate can be varied by adjusting the variable speed drive, changing the impeller, changing the motor to one of a different speed, or installing a gate valve to throttle the flow leaving the pump (essentially acting as an orifice). Every effort should be made to match the desired discharge rate with a reasonable infiltration area.

3.5.4 Design of Conveyance Pipe

The sump runoff will be discharged through the conveyance pipe, which is normally connected to the distribution pipe. The size of the conveyance pipe will vary depending on whether a gravity or pump flow mechanism is used. Under most conditions, a 100 mm (4 in.) diameter pipe will be adequate to accommodate the flow generated by gravity. Larger pipe sizes may be required if the pipe capacity is inadequate to accommodate the required discharge flow rate.

A pump, under most conditions, will require a 38.1 mm (1.5 in.) or 50.8 mm (2 in.) conveyance pipe. These are standard discharge pipe sizes for small sewage pumps. These two pipe sizes will be able to accommodate a large range of discharge rates. Additional flow can be achieved in these pipes by increasing the pump size and capacity (e.g., more horsepower).

In VFS systems that utilize gravity flow, the slope of the conveyance pipe dictates the ultimate capacity and velocity that can be achieved in the pipe. The slope of the pipe is determined by dividing the grade change between the inflow and outflow elevation of the conveyance pipe by the length of the pipe. The inflow elevation is obtained from the conveyance pipe elevation in the sump, and the outflow elevation is established at the connection with the distribution pipe. A minimum flow velocity of 0.6 m/s (2 ft/s) should be maintained when the 100 mm (4 in.) pipe is flowing full to prevent the settling of suspended particulate matter in the pipe. This is the fundamental limitation on the use of gravity flow. If adequate slope is not available to achieve the minimum flow velocities in the conveyance pipe, then a pump must be utilized. The conveyance pipe should be sloped such that the water will drain into the distribution pipe and infiltration area once the pulsed discharge event is complete.

In VFS systems that utilize a pump, the total head differential between the inlet and outlet elevation of the conveyance pipe, along with frictional losses associated with pipe run bends and curves, are factored into the selection of the pump size and associated pipe size. The distribution pipe is designed to work under a pressure head of 0.9 m (3 ft) to obtain uniform distribution through orifice holes onto the infiltration area. This pressure head has to be accounted for in calculating the total head that the pump must deliver against. All of the conveyance pipe should be sloped back into the sump. If the pipe can not drain fully or be buried below frost level, it must be insulated and heat traced, e.g., pipe protected with heating cable installed around or along the pipe.

Design Process

In order to size the conveyance pipe, a general idea of the layout of the conveyance pipe run is necessary. The following information will need to be gathered to determine the pipe size:

- the required discharge rate of the pump to the conveyance pipe
- material of construction of the pipe
- slope of the pipe (inlet/outlet elevation of conveyance pipe and run length between inlet and outlet point) in a gravity system or head differential (inlet/outlet elevation of conveyance pipe) plus other frictional losses in a pumped system

A more detailed description of the above design elements of the conveyance pipe are discussed below.

Pump Discharge Rate to Conveyance Pipe The pump should be designed for target discharge capacity that is 10 per cent greater than the storage/settling basin discharge.

Material of Construction of Pipe A PVC pipe will be suitable for most VFS system applications. However, several other piping options are suitable, depending on the VFS system design. Always check with pipe manufacturers to ensure that the selected pipe is suitable for:

- wastewater applications
- predicted load conditions
- pressurized situations

If the pipe is expected to bear stress from traffic or other sources, provide adequate protection to ensure that the pipe won't be damaged.

Conveyance Pipe Slope in Gravity System or Head Differential in Pump System
For a gravity system the slope of the conveyance pipe dictates the capacity and velocity that can be achieved in the pipe. The pipe slope is determined by dividing the inlet/outlet elevation difference of the conveyance pipe by the pipe run length. A minimum flow velocity of 0.6 m/s (2 ft/s) should be maintained when the conveyance pipe is flowing full.

In pump systems the total head differential between the inlet and outlet elevation of the conveyance pipe, along with frictional losses associated with the pipe are factored into the selection of the pump size and associated pipe size. The distribution pipe pressure head of 0.9 m (3 ft) is also accounted for in the calculation of the total head.

The Darcy-Weisbach Equation is used to calculate friction losses in the piping system.

Equation 3.8
Darcy-Weisbach equation

$$h_f = f(L/D)(V^2/2g)$$

Where: h_f = head loss due to friction (m)
f = friction factor (use 0.020)
L = length of pipe (m)
D = inside diameter of pipe (m)
V = average velocity of flow (m/s)
g = acceleration due to gravity (m/s^2)

Localized friction losses due to pipe bends, valves, etc. should be accounted for, although in most cases they will represent a small percentage of the total losses due to friction.

3.5.5 Manning's Equation for Establishing Pipe Size

Manning's Equation is the most widely used formula for determining the hydraulic capacity of a pipe for gravity and pressure flows. Equation 3.9 outlines the variables, units, and mathematical relationship to establish or confirm a pipe size. The intent is to confirm that with the use of gravity flow, sufficient slope is available to generate the required flow velocity in the conveyance pipe. A 100 mm (4 in.) diameter pipe size will be evaluated based on a target discharge flow rate that is 10 per cent greater than the orifice opening required to transfer the conservative maximum storage volume in an integrated storage/settling basin over a four-hour period (value established in a earlier example). The process should be repeated again to ensure that the 100 mm (4 in.) pipe is capable of accommodating the longer discharge period of 10 hours and the associated 10 per cent higher discharge rate. The equation is rearranged to solve for the slope of the pipe. If the slope available is greater than the slope calculated, then the pipe size is acceptable.

Equation 3.9

Manning's equation

$$Q = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

which can also be written as

$$V = \frac{R^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

since

$$Q = VA$$

Therefore

$$S = \left[\frac{Vn}{R^{2/3}}\right]^2$$

Where: Q = flow rate (m^3/s)
A = area of pipe (m^2)
S = slope of pipe (m/m)
R = hydraulic radius = area of water flow in pipe divided by the wetted perimeter of pipe
n = Manning's n, PVC Pipe (smooth inner walls) = 0.009
V = velocity of flow (m/s)

For example, if the integrated storage/settling basin is to be drained in a 4-hour period then the following assumptions can be made: a 0.1 m (4 in.) diameter pipe will be evaluated (pipe radius = 0.05 m), a flow rate of 5.3×10^{-3} m^3/s (0.19 ft^3/s) (orifice flow rate for desired drain period of 4.8×10^{-3} m^3/s (0.17 ft^3) increased by 10%), a flow velocity of 0.6 m/s (2 ft/s) (minimum velocity to reduce solids buildup, also derived from Manning's equation Q = VA and solved for V). The above variables were incorporated into Manning's equation and the equation was solved for the slope. The slope = $\{(0.6\ m/s \times 0.009)/[(\pi \times (0.05\ m)^2)/(\pi\ (2)\ (0.05\ m)]^{2/3}\}^2$ = 0.004 m/m (0.004 ft/ft). A slope of 0.4% is adequate to accommodate the 100 mm (4 in.) diameter pipe for the specified flow to maintain the minimum velocity of 0.6 m/s (2 ft/s).

However, if the same exercise is carried out for the 10-hour drainage period, there is insufficient velocity generated by the 100 mm (4 in.) pipe for the lower discharge rate. The result would indicate that a pump may be required if the full range of the flows (within the 4 to 10-hour drainage period) is to be accommodated. An iterative process would need to be carried out to verify the drainage period and a corresponding discharge rate accommodated by the 100 mm (4 in.) diameter pipe, before the velocity in the pipe decreases below the target 0.6 m/s (2 ft/s) required.

3.6 Design of Distribution System

The purpose of the distribution system is to evenly distribute the runoff water across the full width of the top edge of the infiltration area. The recommended method is to use a raised distribution pipe. However, a distribution channel may be used under the following conditions:

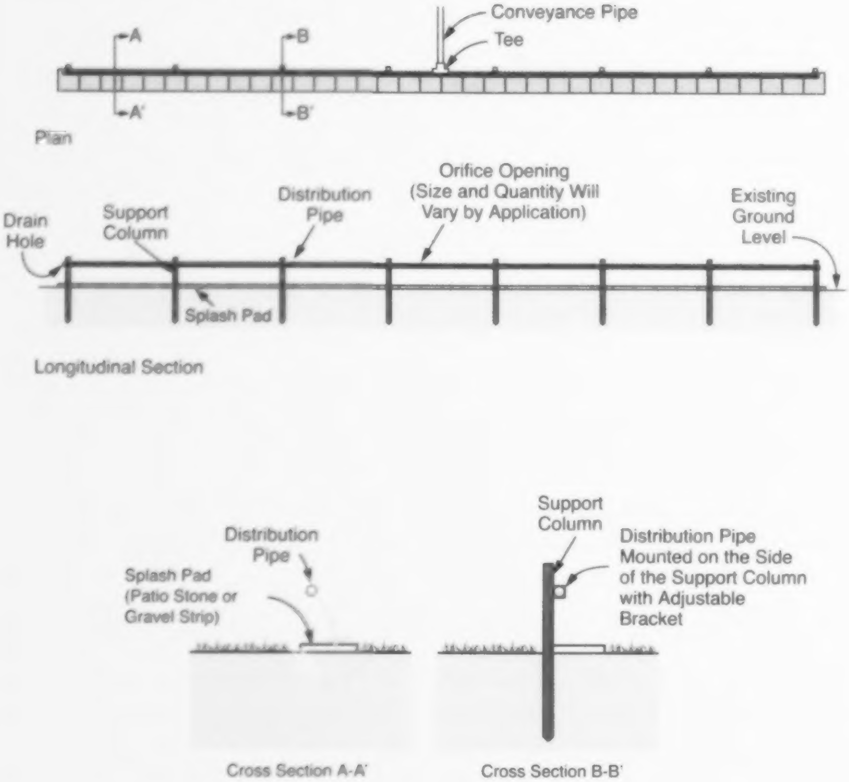
- There is insufficient slope at the conveyance outlet to accommodate the raised pipe.
- The runoff can be directly discharged from the integrated storage/settling basin and flow is transferred to the infiltration area via gravity.

While the focus within much of this manual will be on the development of a raised distribution pipe, the design parameters associated with both a raised distribution pipe and distribution channel are presented below.

3.6.1 Raised Distribution Pipe

The conveyance pipe will discharge into the distribution pipe, as illustrated in Figure 3.6. In addition, Figure 3.6 describes a raised distribution pipe. The size of the distribution pipe should be calculated using Equation 3.9. A minimum pipe diameter of 100 mm (4 in.) is recommended. The conveyance pipe will penetrate the distribution pipe about midway along its length. A grade for the distribution pipe of 0.1 per cent to 0.3 per cent in both directions from the conveyance pipe connection is recommended. The distribution pipe will be raised 0.5 m to 1 m (1.6 ft to 3.3 ft) above the finished surface of the ground. The distribution pipe will be fastened to support columns (0.1 m x 0.1 m (4 in. x 4 in.) pressure-treated wood) using galvanized pipe clamps. The interval between support columns will be short enough to ensure that the distribution pipe does not sag between columns (typically between 2.4 m (8 ft) and 3 m (10 ft)). The column spacing should take into account pipe joints to allow for adjustment of pipe sections if required. The pipe joints should be situated between support columns. Additional support, e.g., distribution pipe attached to a continuous plank system running between the support columns, may be provided under the pipe in an effort to minimize the number of support columns required (depending on the diameter of distribution pipe). The distribution pipe installed on the top of each slope of the infiltration area will be loose-fitted using bell ends or couplings. The conveyance pipe and tee union connection to the distribution pipe will be hard-fitted. The distribution pipe joints should be screwed together to retain the distribution pipe position.

Figure 3.6
Raised distribution pipe



Orifices located at design spacing along the length of the pipe provide uniform application. The flow from each orifice is controlled by the size of the orifice and supply pressure (9 to 14 kPa or 1 to 2 psi). The application rate across the top of the infiltration area is determined by the orifice spacing.

Orifices may be placed on one side of the pipe or on both sides for use with back-to-back configurations. Orifices may be variable or fixed. The most common type of variable orifice-pipe is gated aluminum or PVC pipe, such as those used for furrow irrigation. Gates are plastic slide closures that can be adjusted by hand to achieve the desired flow and uniformity of distribution. A minimum gate spacing of 0.6 m (2 ft) is recommended. Fixed orifice pipes consisting of rigid PVC pipe with drilled holes (at a design spacing) can also be used, but provide less operating flexibility than gated pipes. The orifice capacity will be 25 per cent greater than the flow rate delivered by the conveyance pipe to allow for potential clogging of orifices.

A drain hole will be situated at the ends of the distribution pipe to allow all water to discharge from the pipe after delivery of runoff. The drain hole diameter will be 0.005 m. More than one drain hole at either end of the distribution pipe may be required depending on overall length of pipe and slope variations in pipe along length (e.g., no standing water should remain in pipe).

Splash Pad

The splash pad will protect the infiltration area from erosion and assist in even flow distribution to maintain sheet flow over the VFS. A splash pad will be installed beneath each orifice opening using a standard 0.6 m x 0.6 m (24 in. x 24 in.) concrete patio stone or other suitable energy dissipation measure.

3.6.2 Design of Raised Distribution Pipe

The design requirements of the raised distribution pipe include the sizing of the distribution pipe, establishing the number of orifice openings, and the spacing of the orifice openings along the length of pipe.

Pipe diameters and orifice openings must be large enough to prevent clogging with solids. The minimum standard size for gated irrigation pipe is 152 mm (6 in.), but 100 mm (4 in.) diameter pipe can be specially fabricated.

The design of the raised distribution system will be based on the following design parameters:

- Calculate the pipe diameter using Equation 3.9, assuming slope of pipe between 0.1 and 0.3 per cent and that the pipe will be full. Verify that the velocity of flow is at least 0.6 m/s (2 ft/s). Use a minimum 100 mm (4 in.) diameter pipe.
- Increase orifice capacity in distribution pipe by 25 per cent of flow being delivered from the conveyance pipe to the distribution pipe to account for blockage of orifice holes in distribution pipe.
- Assume the head at orifice holes to be 0.9 m (3 ft).

If the supply rate exceeds the capacity of the perforations at minimum head, then the pipeline will flow full, the head will increase, and the flow through the perforations will increase due to the higher available head.

With a pumped system or through a dosing siphon, it is possible to ensure the pipe is fully charged to provide better flow distribution down the pipe. Either the pumped or dosing siphon alternatives require that the distribution piping not be oversized for the planned supply flow rate.

Step 1—Establish Discharge Capacity of Orifice in Distribution Pipe

Use orifice discharge capacity equation (Equation 3.7) and solve for Q assuming an orifice size of 10 mm (0.4 in.) and a head of 0.9 m (3 ft).

$$Q = CA(2gh)^{0.5}$$

For example, the following values would be used for the equation variables: C of 0.61, A of $7.85 \times 10^{-5}\ m^2$ *(*$84.5 \times 10^{-5}\ ft^2$*), g of* $9.8\ m/s^2$ *(*$32.2\ ft/s^2$*), h of 0.9 m (3 ft). The resulting discharge would be* $(0.61) \times (7.85 \times 10^{-5}\ m^2)\ [(2)\ (9.8\ m/s^2)\ (0.9\ m)]^{0.5} = 2.0 \times 10^{-4}\ m^3/s$ *(*$0.007\ ft^3/s$*).*

Step 2—Establish the Number of Orifice Holes to Meet Flow Capacity Being Delivered Plus an Additional 25 Percent

For example, assuming that a flow rate of $5.3 \times 10^{-3}\ m^3/s$ *(*$0.19\ ft^3/s$*) is being delivered to the raised distribution pipe from the conveyance pipe, then the target discharge volume for the distribution pipe increased by 25% would be* $6.63 \times 10^{-3}\ m^3/s$ *(*$0.23\ ft^3/s$*). Divide the target discharge rate for the distribution pipe of* $6.63 \times 10^{-3}\ m^3/s$ *(*$0.23\ ft^3/s$*) by the orifice discharge rate of* $2.0 \times 10^{-4}\ m^3/s$ *(*$0.007\ ft^3/s$*) to determine the number of orifice holes required along the length of discharge pipe. The result would be* $(6.63 \times 10^{-3}\ m^3/s)/(2.0 \times 10^{-4}\ m^3/s$ *per orifice) = 33. Ensure that there is an even number of orifices, so make 34 orifices. Do not place an orifice in the tee (centre of the distribution pipe). If you use a larger diameter orifice, then you will need fewer orifices.*

Step 3—Determine the Spacing of the Orifices Along the Distribution Pipe

For example, if the distribution pipe is 100 m (328 ft) long then the spacing between the 34 orifices would be equal to 100/34 = 2.94 m (9.7 ft). Start drilling the orifices from the centre of the pipe run (intersection of tee of conveyance pipe and distribution pipe) and place the first orifice half the spacing distance from the centre of the run (tee). This will evenly distribute the orifices on either side of the distribution pipe, placing the last orifice on each side of the pipe, half the spacing distance from the end of the pipe.

3.6.3 Distribution Channel

A typical distribution channel will consist of a 0.3 m (1 ft) deep channel with banks that have a slope of 1:1 and a flat bottom that is 0.3 m (1 ft) wide, spanning the width of the infiltration area. The downgradient edge of the channel will be graded so that the edge will be level along the entire length of the channel. The channel will be filled with 30 to 50 mm (1.2 in. to 2 in.) diameter gravel that will extend downgradient of the channel edge about 0.5 m (1.6 ft). This design will provide erosion protection and reduce the potential for blockage of the distribution system as a result of freezing temperature.

3.7 Design of Infiltration Area

The infiltration area is the final destination of the collected and stored runoff. The infiltration area must be designed to accommodate the entire runoff volume (at the defined discharge rate from the storage/settling basin) in order to generate a zero-discharge system (none of the runoff leaves the defined infiltration area boundary). The design of the infiltration area involves:

- Establishing the size of the infiltration area required, based on the greater area requirement of:
  - the saturated hydraulic conductivity of the soil and the loading rate from the storage/settling basin
  - the maximum allowable liquid loading on the infiltration area of 0.05 m (2 in.) per week
- Establishing the width-to-length ratio of the infiltration area based on:
  - a 15-minute retention time over the length of the infiltration area
  - a maximum water depth of 0.0127 m (0.5 in.)

The infiltration area must be flat across the width. The infiltration area slope along the length should be consistent across the whole infiltration area and between 2 and 12 per cent. Areas of the farmstead that possess consistent slopes in this range should be identified for consideration as an infiltration area.

3.7.1 Determining Infiltration Area Size

In order to accommodate the zero discharge system, the infiltration area size is spatially defined by the saturated hydraulic conductivity of the soil and the volume of water that it receives. The following describes the importance of saturated hydraulic conductivity, defines the method for establishing saturated hydraulic conductivity values, and explains the process for defining the infiltration area.

Saturated Hydraulic Conductivity

Establishing soil characteristics in the proposed infiltration area is the most critical component of determining the size of the infiltration area. Hydraulic conductivity is a soil characteristic that defines the rate at which water travels through soil in metres per day. Saturated hydraulic conductivity is the rate of flow when the soil is completely saturated (e.g., soil is not able to store any of the contributing water) and a zero or minimal depth of water ponding exists on the soil surface. Soil scientists have been able to establish approximate saturated hydraulic conductivity values for various soil types based on the textural composition of the soil. This manual uses soil texture values to estimate associated saturated hydraulic conductivity values. Subsequent on-site analysis will be carried out to measure the actual saturated hydraulic conductivity of potential infiltration areas.

The size of the infiltration area is directly related to the capacity of the soil to infiltrate the applied flow volume (known as "areal loading capacity"). Fine-textured soils generally have a lower saturated hydraulic conductivity and, therefore, a slower rate of water travel through the soil than coarse-textured soils. Therefore, the area required for an infiltration area on fine-textured soil is greater than on coarse-textured soils, for the same hydraulic loading rate. For this reason, the integrated storage/settling basin is the preferred storage option since it is able to retain the entire 25-year/24-hour storm event and discharge that volume over an extended period of time. This reduces the areal loading to the infiltration area and subsequently reduces the required infiltration area. The ultimate aim of the infiltration area is to accommodate all of the flow contributed to it, resulting in a zero-discharge system.

Methods to Establish Saturated Hydraulic Conductivity A three-step method is proposed to determine the saturated hydraulic conductivity of the soil. Methods 1 and 2 use soil texture data derived from historical soil survey maps or from soil samples taken in the field and laboratory analysis results. These two methods should be used to gain a general understanding of the soil characteristics of the proposed infiltration area in order to evaluate the viability of the soil to support a VFS system. It is recommended that both Method 1 and 2 be carried out as part of the initial evaluation process. If Methods 1 and 2 deem the soils suitable, then Method 3 should be carried out. Method 3 involves an on-site evaluation of the proposed infiltration area using a suitable method or device carried out by a soil specialist. The following outlines in detail the three methods.

Method 1—Using Existing Historical Site Information

Previous soil texture analyses may have been conducted for the proposed infiltration area. These may provide some information on the existing soil texture, particle size distribution, and hydraulic conductivity. However, in the absence of any site-specific historical data, an evaluation of Ontario Soil Survey Map information may also be useful to estimate the saturated hydraulic conductivity of the proposed site based on the soil groups. It is important to note that the soil map provides a broad general description of the province and in some instances it may be difficult to accurately determine the soil group of the proposed infiltration area from this method. The method involves the following:

1. Determine soil series from an Ontario Soil Survey Map (available from OMAFRA resource centres).
2. Determine soil texture within soil series from the Ontario Soil Survey Map or by accessing any historical data for the farm site through OMAFRA resource centres or from well-drilling records.
3. If the site proposed for the infiltration area is comprised of two different soil series or textures, the most conservative (e.g., finest texture or lowest saturated hydraulic conductivity) soil type should be considered to determine minimum VFS area requirements.
4. See Table 3.2 to determine the associated saturated hydraulic conductivity of the soil texture and choose the soil texture with the lowest saturated hydraulic conductivity for use in sizing the infiltration area.

Table 3.2
Soil texture class and typical hydraulic conductivity under saturated soil conditions

Soil Texture Class	Typical Hydraulic Conductivity (m/d) [a]
Sand	5.04
Loamy Sand	1.466
Sandy Loam	0.6216
Loam	0.3168
Silt Loam	0.1632
Sandy Clay Loam	0.1032
Silt	0.06
Clay Loam	0.0552
Silty Clay Loam	0.036
Sandy Clay	0.0288
Silty Clay	0.0216
Clay	0.0144

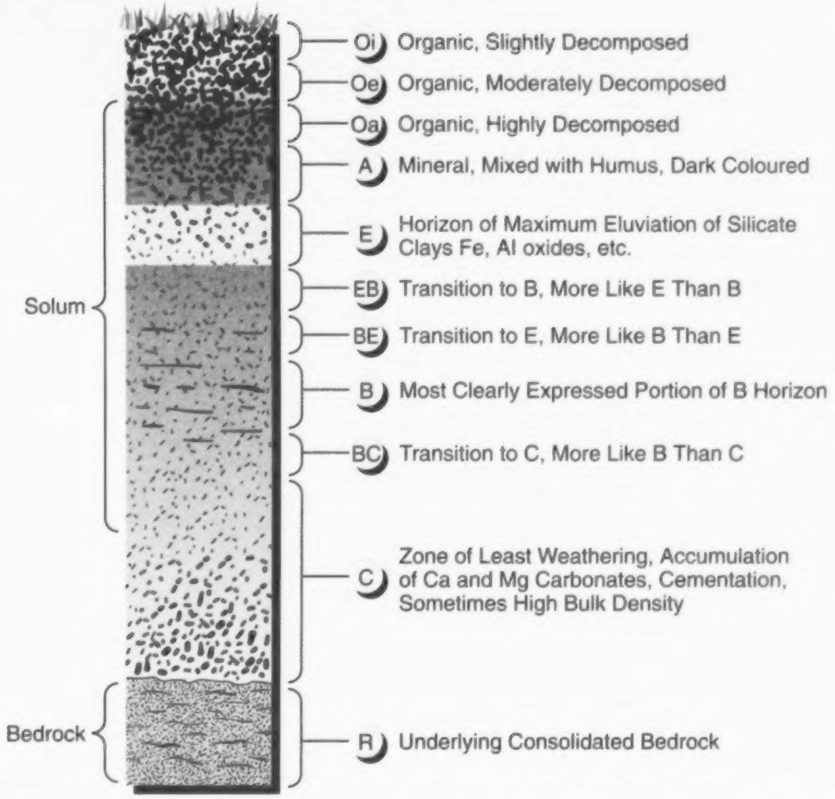
[a] *The RETC Code for Quantifying the Hydraulic Factors of Unsaturated Soils* (Dec 1991), van Genuchten, M.Th.; Leij, F.J.; Yates, S.R. Rawls et al (1982) for all textures except silt, which is obtained from Carsel & Parrish (1988)

Method 2—Soil Texture Determined by Laboratory Soil Test Results

In addition to any historical data that is gathered, sampling and particle-size analysis will be required to determine the actual texture of the soils in the proposed infiltration area. This information can be cross-referenced with the historical data to confirm or contradict previous data. This method will require collecting soil samples and shipping the samples to an accredited laboratory for analysis of particle-size distribution and determination of soil texture. The following process can be used to establish the number of samples, sampling depth, and method for sampling:

1. Establish the extent of the suitable infiltration area and establish one sample location for each proposed infiltration area site. Place a wooden stake in the field to mark the sample location for future reference. An additional sample site may be required if there is significant variation in the soil type.
2. Excavate a shallow test pit at the sample location to determine the depth of each of the soil horizons present to a maximum depth of 1.5 m (4.9 ft). See Figure 3.7 for an illustration of soil horizons. Depth of excavation will vary depending on several factors, including water table elevation, bedrock elevation, and variability of soil within each horizon.

Figure 3.7
Soil horizons


Oi Organic, Slightly Decomposed
Oe Organic, Moderately Decomposed
Oa Organic, Highly Decomposed
A Mineral, Mixed with Humus, Dark Coloured
E Horizon of Maximum Eluviation of Silicate Clays Fe, Al oxides, etc.
EB Transition to B, More Like E Than B
BE Transition to E, More Like B Than E
B Most Clearly Expressed Portion of B Horizon
BC Transition to C, More Like B Than C
C Zone of Least Weathering, Accumulation of Ca and Mg Carbonates, Cementation, Sometimes High Bulk Density
R Underlying Consolidated Bedrock
Solum
Bedrock

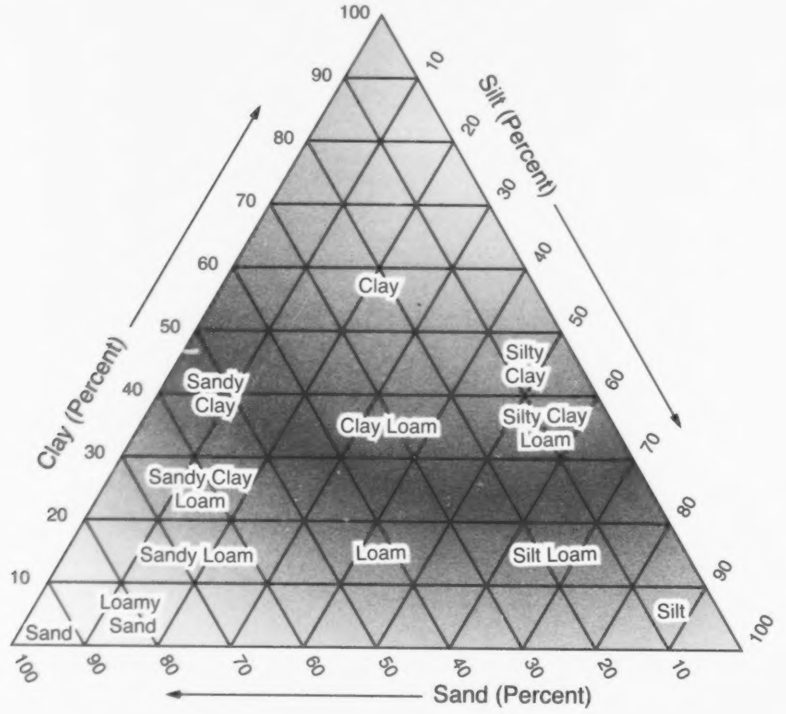
Source: Nyle C. Brady and Ray R. Weil, 1996. The Nature and Properties of Soils, 11th ed., New Jersey: Prentice Hall,

3. One individual soil sample will be required from each of the different soil horizons encountered. Sample size should be equal to a volume that measures approximately 5 cm x 5 cm x 10 cm (2 in. x 2 in. x 4 in.). On each sample, identify the sample location and the depth at which the sample was taken. Draw a cross-section of the test pit to illustrate the profile of the soil, the marking of the soil horizons (depth below grade), and the location where each sample was taken.

4. Send the individual soil samples from each horizon to a soil-testing laboratory for particle-size distribution analysis. A list of accredited soil-testing laboratories can by found on the OMAFRA website, or by contacting an OMAFRA resource centre.

5. Compare particle-size distribution results from the laboratory for each soil horizon with Figure 3.8 to determine a soil texture. See Table 3.2 to determine the associated saturated hydraulic conductivity of the soil texture and choose the soil texture with the lowest saturated hydraulic conductivity for use in sizing the infiltration area.

Figure 3.8
Soil texture by particle-size distribution



Method 3—On-site Evaluation

Use Method 3 after confirming the viability of the VFS system using the data generated by Methods 1 and 2. Method 3 should be carried out to support the detailed design of the VFS system. A qualified professional should perform an on-site saturated hydraulic conductivity test using a Guelph Permeameter, Cylinder Infiltrometer, or other equivalent method. The on-site analysis should be carried out on the most limiting soil horizon (lowest hydraulic conductivity soil) based on the soil texture results from Method 2.

Determination of Minimum Area Required for Infiltration Area

A two-stage process is required to determine the minimum area required for the VFS system infiltration area. Stage 1 involves establishing an infiltration area size based on the saturated hydraulic conductivity of the soil and the discharge rate coming from the storage/settling basin. Stage 2 establishes an infiltration area based on a maximum allowable liquid loading on the infiltration area of 0.05 m (2 in.) per week, or less. The greater area requirement of each evaluation process dictates the minimum size of the infiltration area.

Stage 1—Saturated Hydraulic Conductivity of Soil The minimum area required for the infiltration area is determined by dividing the flow from the storage/settling basin by the saturated hydraulic conductivity of the soil. The following outlines the evaluation process:

1. Establish a typical saturated hydraulic conductivity value for the soil texture determined from Method 3.
2. Establish the runoff discharge flow being delivered to the infiltration area from the storage/settling basin.
3. Determine *minimum* area required for infiltration area by dividing the discharge flow from the storage/settling basin by the saturated hydraulic conductivity.

For example, a flow of 5.3 x 10^{-3} m^3*/s (0.19* ft^3*/s) divided by a saturated hydraulic conductivity value of 0.3168 m/d (1.04 ft/d) for a loam soil would be calculated as follows: (5.3 x* 10^{-3} m^3*/s)/(0.3168 m/d x 1/86,400 s/d) = 1,445* m^2 *(15,559* ft^2*). The area required would be 1,445* m^2 *(15,559* ft^2*).*

From Table 6.3 for a flow of 5.5 x 10^{-3} m^3*, the area required for infiltration on the loam soil is 1,500.27* m^2 *(16,149* ft^2*).*

Stage 2—Maximum Allowable Liquid Loading The maximum allowable liquid loading on the infiltration area is 0.05 m (2 in.) per week, or less. The following steps should be taken to determine the minimum size of infiltration area based on liquid loading limit. Use Table 3.3 to establish the highest monthly precipitation values for Ontario sites to determine the available liquid loading capacity of the infiltration area.

Table 3.3
Highest monthly precipitation for various Ontario locations

Station Location	Highest Monthly Precipitation (mm)
Cornwall Ont. Hydro	97.8
Kingston Pumping Station	97.1
Lindsay Filtration Plant	83.6
London Airport	95.3
Mount Forest	97.0
North Bay Airport	108.9
Orillia TS	104.9
Ottawa Cda	87.8
Sarnia Airport	90.1
Simcoe	92.2
Thunder Bay Airport	88.5
Trenton Airport	91.2
Toronto Pearson Int'l Airport	84.2
Waterloo Wellington Airport	93.3
Windsor Airport	97.0

Source: Atmospheric Environment Service. Highest Monthly Precipitation Values (2002). To retrieve current precipitation data visit: *www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html*

1. Use Table 3.3 to determine the highest normal weekly precipitation for the closest station (since the value is reported on a monthly basis, divide the precipitation amount by 4).

   For example, the highest normal weekly precipitation that the Trenton Airport receives is $(91.2 \times 10^{-3}\ m)/4 = 22.8 \times 10^{-3}\ m$ *(0.90 in.).*

2. Calculate outside paved yard or solid manure storage weekly runoff volume (m^3).

   Weekly runoff volume (m^3) = outside yard or manure storage area (m^2) x highest normal weekly precipitation (m)

   For example, the outside yard or manure storage area weekly runoff volume is $(1{,}000\ m^2)(22.8 \times 10^{-3}\ m) = 22.8\ m^3$ *(805* ft^3*).*

3. Calculate limiting precipitation amount per week on VFS.

   Limiting precipitation amount per week on VFS = maximum allowable liquid loading/week (m) – highest normal weekly precipitation (m)

   For example, the limiting precipitation amount per week on VFS is 0.05 m (2 in.) – $(22.8 \times 10^{-3}\ m)$ *(0.90 in.) =* $27.2 \times 10^{-3}\ m$ *(1.07 in.).*

4. Calculate minimum VFS area required (m^2).

   Minimum VFS area required (m^2) = yard or storage weekly runoff volume (m^3)/limiting precipitation amount per week on VFS (m)

   For example, the minimum VFS area required is $22.8\ m^3/(27.2 \times 10^{-3}\ m) = 838\ m^2$ *(9,023* ft^2*).*

   Thus, the minimum infiltration area required in order to meet the liquid loading limit is 838 m^2 (9,023 ft^2).

In comparing the results of Stage 1 and Stage 2 above, the minimum required area for the infiltration strip will be 1,445 m^2 (15,550 ft^2) as calculated using the saturated hydraulic conductivity method (Stage 1).

The required area to accommodate the infiltration area has now been established. This would be a good point to check that the land area available for a potential infiltration area is adequate to meet the area required. If sufficient area is not available to accommodate the required infiltration area, a VFS system may not be possible.

Defining the Infiltration Area Dimensions The determination of the infiltration area dimensions will depend on several factors:

- ensuring that the infiltration area slope along the length is consistent across the whole infiltration area and is between 2 and 12 per cent
- providing a flow length within the infiltration area that accommodates a 15-minute flow-through time from point of discharge to lower extent of the infiltration area
- establishing an infiltration area width that passes the discharge volume from the storage/settling basin at a flow depth of 0.0127 m (0.5 in.) or less

The following defines the method to be used in the determination of the infiltration area length and width.

Minimum Length

The length of the infiltration area is calculated using Manning's Equation as shown in Equation 3.9. The equation will be solved for the velocity of the flow. The variables that are required include the slope of the intended infiltration area (S), the depth of flow (R), and Manning's coefficient (n) for a vegetated channel of 0.24. Once the velocity has been established, the length is then determined by multiplying the velocity by the 15-minute (900 seconds) flow-through time. For a maximum 0.0127 m (0.5 in.) flow depth, the calculated 15-minute flow length is shown in Table 3.4 for slopes ranging from 2 to 12 per cent.

For example, the velocity of the flow in the proposed infiltration area with a slope of 0.04 m/m (0.04 ft/ft) (4%), a depth of flow of 1.27×10^{-2} *m (0.5 in.), Manning's coefficient of 0.24, is* $(1.27 \times 10^{-2}\ m)^{2/3} \times (0.04\ m/m)^{1/2}/0.24 = 45.4 \times 10^{-3}\ m/s$ *(0.149 ft/s). The length is determined by multiplying the velocity of* 45.4×10^{-3} *m/s by the minimum flow-through time of 900 seconds as follows* $(45.4 \times 10^{-3}\ m/s)\ (900\ s) = 41\ m$*.*

Table 3.4

15-minute flow length for 0.0127 m (0.5 in.) flow depth (Manning's coefficient = 0.24)

Slope (%)	Velocity (m/s) (x 10^{-1})	Flow Length (m)
2	3.21	29
3	3.93	35
4	4.54	41
5	5.07	46
6	5.56	50
7	6.00	54
8	6.42	58
9	6.80	61
10	7.17	65
11	7.52	68
12	7.86	71

If sufficient length is not available in the proposed infiltration area, the flow depth can be reduced to accommodate the available length. As a result, the minimum width of the infiltration area will increase.

Minimum Width

The minimum width of the infiltration area is calculated from Equation 3.10. The variables that are required include the discharge rate from the storage/settling basin (q_p), the depth of flow (d) and the velocity of the flow (V). The width is equal to the discharge flow from the storage/settling basin divided by the product of the depth of flow times the velocity.

Equation 3.10

Filter strip minimum width equation

$$W = \frac{q_p}{(d)(V)}$$

Where: W = VFS minimum width (m)
q_p = peak flow (m^3/s)
d = depth of flow (m)
V = velocity of flow m/s

For example, an infiltration area with a discharge rate of 5.3×10^{-3} m^3/s (0.19 ft^3/s) from the runoff storage/settling basin, a water depth of 1.27×10^{-2} m (0.5 in.) and a velocity of 45.4×10^{-3} m/s (0.15 ft/s) has a width equal to $[(5.3 \times 10^{-3}\ m^3/s)/(1.27 \times 10^{-2}\ m)(45.4 \times 10^{-3}\ m/s)] = 9.2$ m (30.16 ft).

Select the Ultimate Dimensions for the Infiltration Area Select the final dimensions for the infiltration area that are equal to or greater than the minimum length and width calculated, and at the same time meet the minimum area requirement for Stage 1 and Stage 2 calculations. The minimum area requirement is as calculated using the saturated hydraulic conductivity method (Stage 1). The minimum length and width have been calculated using Equations 3.9 and 3.10 respectively.

Compare the minimum area required for the infiltration area to the area available. If the minimum area required is greater than the available area, a VFS system may not be suitable for this location.

For example, the greater area requirement as determined by Stage 1 (saturated hydraulic conductivity calculation) dictates the minimum area of the infiltration strip. The infiltration area is 1,445 m^2 *(15,559* ft^2*) with length of 41 m (135 ft) and width of 35 m (115 ft).*

3.7.2 Infiltration Area Design Elements

Inconsistent Slopes

In situations where the existing grade is inconsistent but the overall average slope is suitable for an infiltration area, regrading of the infiltration area will be required. Earth excavation should be limited to dry periods to avoid rutting or compacting the soil. Equipment used to carry out the excavation should use floatation tires in order to distribute the load of the equipment over a larger surface area. The existing topsoil should be stripped and the subgrade regraded to generate the desired slope. Every effort should be made to minimize the extent of disturbance and compaction during the regrading exercise. The topsoil should be replaced after grading and stabilized with vegetation as soon as possible to avoid erosion of the soil.

In situations with multiple slopes that are consistent, avoid grading. Instead, the calculations carried out to establish the dimensions of the infiltration area should be done for each consistent section and summed up until the required flow path length is achieved to accommodate the 15-minute flow-through time.

Maintenance of Sheet Flow

Overland flow will tend to converge as it flows through the infiltration area. Maintenance of sheet flow for more than 30 to 50 m (100 to 160 ft) on 2 to 5 per cent slope is difficult without some sort of intervention. Level grading of the infiltration area across its width promotes sheet flow. Spreaders may be constructed as rock or gravel berms. These spreaders should extend above the ground surface only a few inches to allow for flow spreading without extensive ponding of flow. The design, operation and maintenance plan for these spreaders should include provisions for periodic relevelling.

Constructed spreaders will not need to be as structurally secure (as might be required) for the inlet distribution system, but they still should be able to remain structurally intact under high-flow conditions.

Vegetative Cover

The infiltration area should be densely vegetated, with a mix of local and/or native plant species that can tolerate fluctuating soil moisture conditions (saturated to dry soil conditions), will form a dense root system (for erosion protection), and are adaptable to local soil and climatic conditions. Invasive species should be avoided.

The existing grass stand may be suitable if the area does not need grading. It may be necessary to seed into an existing stand of grass to shift the growth into a preferred grass species or mix.

Select specific plant species based on the intended use of the infiltration area vegetation. In some cases, the infiltration area may be used to generate hay or silage. In this instance, a permanent long-term agricultural forage seed mix is recommended to limit the need for reseeding. The type of forage crop will vary across the province; contact local seed co-ops/suppliers for advice. In other cases, where the infiltration area only serves to accommodate runoff from the collection area, a variety of grass species along with legume species should be used to vegetate the area.

Select forages and other crops based on the following considerations:

- **Tolerance to some flooding and saturated soil conditions for extended periods.** An infiltration area receiving liquid from a storage/settling basin over an extended period (4 to 10 hours) will require plants to withstand extended periods of saturated soil conditions.
- **Tolerance to salts.** Select an appropriate forage or grass for its salt tolerance, avoiding low-tolerance plant materials. A separate grass or forage species may be preferable for the first 10 to 15 m (30 to 50 ft) of the infiltration area, where solids settling and infiltration of runoff will be greatest.
- **Tolerance to ammonia.** Many plants cannot tolerate high concentrations of ammonia. Typical feedlot runoff may contain higher ammonia concentrations (400–700 mg/L) than plants can tolerate, although actual concentrations may vary significantly. Higher concentrations are expected from densely stocked lots and infrequently scraped lots. If higher ammonia concentrations enter the infiltration area than the plants can tolerate, vegetation will be lost. If high concentrations are anticipated, blending the settling basin effluent with outside "clean" water may be needed to lower the influent concentration to about 200 mg/L. Blending may result in a larger infiltration area.
- **High evapotranspiration rates.** The total water volume can be reduced if a forage or grass is selected for its high evapotranspiration rates. Long-growing season crops offer advantages for nutrient uptake and evapotranspiration.
- **Perennials.** Infiltration areas should use perennial vegetation that provides growing plants from early spring into late fall for maximum nutrient uptake and water evapotranspiration. Combinations of warm and cool season grasses can create a long growing season in many applications. Sod-forming grasses are preferable to bunch-forming grasses because the sod-forming grasses maintain uniform cover and provide

good sheet-flow conditions. Planting grass and legume species that favour the specific soil type will result in a successful and persistent vegetative stand. The mix should be developed based on the soil conditions of the infiltration area. Avoid invasive species and short-lived species.

- **Large root mass.** Large root mass and surface area encourage microbial activity. Aerobic decompositions of organic solids, and mineralization and nitrification of nitrogen in runoff require active biological environments. Plants with large root mass contribute to an active biological environment. Plants that produce large tap roots are undesirable, increasing the potential for preferential flow, e.g., rapid downward movement of liquid through soil profile to water table.

An intensive vegetation management strategy would be to employ different vegetative zones along the infiltration area. Salt accumulation is typical near the inlet of the runoff to the vegetative area. Planting crops that are salt tolerant near this inlet area would improve sustainability. Also, planting crops that use greater amounts of nitrogen and phosphorus near this inlet would minimize nutrient buildup.

Some of the common species that could be considered include the following, based on soil type:

Poorly Drained Soils (silt-based)

- **Reed Canary Grass.** This is a popular grass species that thrives in poorly drained soil conditions. This species is highly persistent and will quickly form a monoculture and out-compete all other species. It is a sod-forming species with good erosion protection capabilities. It will form an extremely dense vegetative cover and may eventually restrict flow. There is a native variety available, but most commercially available seed stock is an agricultural variety (European) that is non-native.
- **Kentucky Bluegrass.** This is another popular cool-season sod-forming grass species that will do well in somewhat poorly drained soil conditions. It prefers fertile soils. It has a fairly low tolerance to drought and will go dormant during prolonged dry spells. However, it will come back after drought periods. It produces a dense but shallow root structure, spreading by rhizomes. The vegetative cover is fairly short and dense. It is a good candidate for sites that are not easily accessible and will receive minimal maintenance.
- **Orchard Grass.** This is a cool-season bunch-forming grass that does well in somewhat poorly drained soils. It should be planted in a mix with other cool-season sod-forming species.
- **Tall Fescue.** This is another cool-season sod-forming grass species that will do well in somewhat poorly drained soil conditions. Tall fescue does not blend well with other cool-season grass species and is best seeded on its own. It has excellent heat and drought tolerance due in part to its deep rooting system. It prefers fertile soil but will tolerate low fertility. Tall fescue cultivars containing endophytes should not be used if livestock might be grazing on the grass. Fescue toxicosis may result in poor livestock performance that will lead to health issues. Endophyte-free seed is available and should be used if livestock will be grazing in the infiltration area.

- **Perennial Ryegrass.** This is a fast-growing species that will provide quick cover during the initial germination period. The grass species is short lived in Ontario. It should be planted in combination with other grass species and used as a nurse-type crop. Ryegrass also comes with endophytes and should be avoided if livestock will graze in the infiltration area.
- **Smooth Bromegrass.** This is a sod-forming grass with a shallow root system that spreads by means of short rhizomes and seed. The growth is tall.
- **Timothy.** This is a bunch-forming grass that should be planted in combination with other sod-forming grass species.
- **Legumes.** There are a variety of legume species that favour silty soils and wetter soil conditions. These include Alsike, Red and White clover. These species are relatively short lived and should be planted in combination with other long-lived grass species. These species also favour fertile soil conditions. All have a high nutrient value and should be incorporated into the seed mix if livestock will be grazing in the infiltration area.

Well-Drained Soils (sand-based)

- **Switchgrass.** This is a warm-season grass that will be most active during the summer months. It will tolerate drought conditions and relatively low fertility soils. It is difficult to establish and may take several years. It should be planted in combination with other grass species.
- **Legumes.** There are a variety of legumes species available that favour drier soil conditions. These include Alfalfa and Birdsfoot Trefoil. All have a high nutrient value and should be incorporated into the seed mix if livestock grazing is likely to occur in the infiltration area.

Once the type of seed mix has been selected, evaluate soil fertility. Take a composite soil sample of the area intended to accommodate the VFS, and send it to a laboratory for a fertility analysis (pH, plant available nitrogen, phosphorous, potassium, magnesium, and organic matter). The laboratory will generate a fertilizer recommendation based on the soil sample analysis.

If the infiltration area is regraded then the seedbed will need to be prepared. The seedbed will need to be cultivated, fertilized (if required) and firmed before seeding. The equipment used on the infiltration area should be driven across the width of the infiltration area whenever possible. This will reduce the potential of creating ridges along the length of the slope, which may be exaggerated by flow of runoff applied to the infiltration area.

The seeding method used for the infiltration area will need to be carefully considered to ensure that the surface soil is not disturbed (to avoid ruts and soil compaction). If the infiltration area is small enough, manual broadcast spreaders should be used to apply the seed. If the infiltration area is large, making manual broadcast seeding impractical, then mechanical means may be used as long as the appropriate equipment is used to minimize disturbances. As an example, appropriate equipment would include floatation tires that evenly distribute the weight of the equipment over a large surface area. A no-till method may be used to introduce other more suitable grass species to the infiltration area. However, this method may require several attempts. If the existing vegetation where the infiltration area will be established is suitable (e.g., able to tolerate wetter soil conditions), it should be retained and possibly supplemented, as required.

The planting period to establish grass will vary based on local climatic conditions. In general terms, spring seeding should occur between spring thaw and mid-March, and fall seeding should occur between August 1 and the end of September. Check with local seed suppliers and confirm the most appropriate season for the local area. The seeding should be co-ordinated so that the least amount of damage is caused to the surface soils of the infiltration area. If possible, equipment activity should be restricted to periods where the soil is dry and compaction can be minimized.

Containment Banks/Berms

To ensure the area dedicated to the infiltration area retains the runoff and excludes other upslope water, a shallow berm (about 0.3 m (1 ft) in height) will be installed around the perimeter of the infiltration area, as required. These berms will also serve as a visible indicator to identify the location of the infiltration area.

Fencing and Access

All infiltration areas must be protected from uncontrolled access, and should be fenced.

Safety Considerations Associated with VFS System Components

The storage basin and sump are hazards when filled with liquid. Sumps and external storage basins should be adequately protected from falling objects, typically with a secure, but removable cover, and fenced to control access.

Winter Operation

Constantly flowing and normally drained components should not freeze in the winter. Therefore, all piping should be installed to maintain a slope that will drain empty when runoff events are not occurring. Depending on the type of installation, heat tracing and insulation may be required on the piping. Buried piping should be installed below frost level wherever possible.

To prevent freezing of the siphon or pump in the sump, the sump should be constructed to allow the pump to be at least 1.2 m (4 ft) below grade (or more, depending on the local frost line). The sump should be covered during the winter with a solid removable cover.

3.8 Preparation of Design Package

3.8.1 Engaging Professional Services

Under the requirements of the Regulation, a qualified professional (typically a professional engineer) must design the VFS system.

Additional professional services may include the following:

- geotechnical services
- laboratory services (soil testing)
- surveyor

OMAFRA can provide resources on retaining professional services. Contact an OMAFRA resource centre for further information.

3.8.2 Contents of Design Package

The design package prepared must contain enough information, as listed below, to determine the appropriateness of the proposed design. Additional relevant information must also be included in the design package and maintained with the VFS system records as part of the Nutrient Management records.

Drawings

The design package should include the following drawings, as a minimum:

- location map of farm including identifiers (Concession and Lot numbers)
- scaled farm plan with grades (topography), showing runoff area, storage (if applicable), infiltration area, watercourses, ponds, wells, septic tank/tile field, and sensitive features
- VFS system profile with grades and slopes

Additional figures may include:

- aerial photograph

Laboratory Analysis

The following laboratory data should be submitted for the site:

- soil texture
- site-specific saturated hydraulic capacity of the proposed VFS infiltration area

VFS System Design

- complete design of VFS system

3.8.3 Specifications

Ontario Provincial Standards, Divisions 1 and 2 provide typical requirements for general and earth grading construction projects. VFS system construction, whether by a contractor or farmer, should meet the requirements of these standards.

Ontario Provincial Standards publications are available from:

Publications Ontario
50 Grosvenor Street
Toronto ON M7A 1N8
Tel: (416) 326-5300
Toll Free in Ontario: 1-800-668-9938
Orders may be faxed to:
Fax: (613) 566-2234
Website: *www.publications.gov.on.ca*

3.8.4 Construction of VFS System

Construction Scheduling

The VFS must be constructed and vegetation established before the system can be used for management of runoff. It is recommended that when grading and vegetation of the VFS are necessary, they be completed in spring or fall, when the vegetation is likely to best establish. The other VFS system components (containment walls, sump, piping, etc.), may be constructed anytime before the implementation of the VFS system.

Inspection of VFS System

Each component of the VFS system must be inspected before connection to up and downslope system components. For example, this includes pressure testing of piping (before burial, if appropriate) to ensure no leaks, etc.

Testing of VFS System

The VFS system must be tested with clean water prior to connection to runoff, serving to demonstrate its ability to perform to the intended hydraulic design. Any deficiencies must be rectified prior to utilization for management of runoff.

3.8.5 Record Keeping

Design Package

The design package must be submitted to OMAFRA for technical review and approval before construction begins. A copy of the design package should be retained within the record keeping system. The design package includes:

- measurements and calculations
- assumptions
- drawings and construction specifications or methods
- contractor bids

Construction

All VFS system construction records must be kept by the farmer. Examples of such records include:

- construction notes
- photographs taken before, after and during construction
- grading/elevation records
- as-constructed (record) drawings

Operations

Operating data includes, but is not limited to:

- operating manual and troubleshooting documentation
- observed flows in storm events
- overflow and VFS discharge observations
- correspondence

Record observations in a chronological diary and review operating data periodically to identify any patterns of operational issues that may require subsequent maintenance.

Maintenance

Record activity reports in a chronological diary, including the date, activity undertaken, reason of activity (such as scheduled maintenance/cleaning or emergency maintenance), materials used, contracted assistance, and all other relevant information.

3.8.6 Inspection

A VFS system is subject to inspection by the MOE at any time as a condition of approval under the Ontario Water Resources Act.

3.9 Operation and Maintenance

3.9.1 Runoff Area and Storage (Integrated or External)

Cleaning

For integrated storage facilities, the manure should be removed routinely from the runoff collection area to maintain a minimum depth and minimize the nutrient uptake by rainwater.

Diversion of Clean Water

The VFS system will be designed based on the premise that the components required to service the runoff area in a storm event are in-place and operating. Ensure that diversion of the upslope water (such as barn roof runoff) is occurring. Regularly inspect upslope diversion equipment, such as gutters and roof downspouts.

3.9.2 Collection/Discharge Bay

Collection/Discharge Bay

The collection/discharge bay must be cleaned regularly to reduce the potential for clogging the riser pipe and drainpipe orifice. *Daily inspection and maintenance activity is required to achieve this.*

Screen Cleaning

Inspect screens after large storm events and clean as required. Periodic cleaning is also recommended.

Sump Inspection

Routine inspection of the silt level in the sump is required to ensure that the solids do not interfere with siphon/pump operation and convey solids to the infiltration area.

3.9.3 Pumps

Controls

The runoff pump operates on a float system, so that the pump starts and stops are activated automatically by the level of water in the sump. The control system must be inspected and tested regularly.

Cleaning

The pump requires regular cleaning to prevent interruption to operations and/or damage. Refer to the manufacturer-supplied pump operations and maintenance manual.

3.9.4 Piping

Cleaning

Flushing of piping may provide the most effective cleaning method. This can be achieved by running clean water through the system at a velocity higher than normally experienced in the system, if possible.

In pumped systems, caution should be taken to maintain flows through the pump as recommended by the manufacturer.

If particular sections of the piping are clogged, disassemble the piping and thoroughly clean at these sections.

3.9.5 Infiltration Area

Splash Pad

The splash pad should be regularly inspected. Levelling and removal of solids and debris may be required.

Spreaders

Periodic maintenance may be required if erosion develops in the spreader. Therefore, spreaders should be inspected periodically (at least annually) to confirm that they are level and functioning properly.

Solids Entry and Plugging

If high suspended-solids content runoff is continuously directed to the infiltration area, it may become clogged as the solids settle. The appropriate design and maintenance of the runoff and storage/settling facilities should prevent this from occurring.

If solids are observed on the infiltration area, the upstream contribution must be investigated. To reactivate the infiltration area, remove any visible solids, till and re-establish vegetation. Runoff must be directed to other nutrient management facilities during this maintenance period. Alternatively, aeration of the infiltration area may be sufficient to remove blockage.

Maintaining Vegetation

Maintenance of the infiltration area is necessary to ensure a healthy and vigorous vegetative cover. Routine inspection of the infiltration area vegetative cover will be required to ensure 100 per cent coverage and consistent sheet flow. Should small breaks in the vegetative cover or erosion rills be observed, immediate action to correct the deficiency is required. During the initial startup period, irrigation of the infiltration area may be required to promote germination of sown seed. Liquid manure or other similar nutrients should not be applied to the infiltration area. However, other fertilizer may be required for initial establishment of the vegetation. Mowing of the infiltration area should occur 3–4 times during the growing season and especially if weed species migrate into the site, or if thatch buildup begins to smother and limit vegetation density. The harvested crop of hay from the infiltration area can be used for livestock feed. Every effort must be made to ensure that any equipment driven on the infiltration area does not impact the integrity of the sheet flow path, compact the soil or alter the infiltration area hydraulic conductivity, or generate rills or ridges parallel to the flow.

Discharge Observations

During the active operating mode, observe the infiltration area regularly to determine whether it meets the objective of zero discharge (off the lower end of the infiltration area) for the maximum-design storm. If discharge is observed, this indicates that the infiltration area is not operating as designed. Determine the cause and take corrective action.

If the infiltration area does not operate with zero discharge under normal operating conditions, it should be removed from service until the problem is solved, and the runoff should be directed to alternative storage, use, or disposal to reduce the potential for adverse effect on the receiving water.

Safety Measures

The infiltration area should be fenced to protect it from uncontrolled grazing. Maintain vegetation by mowing or controlling grazing. Fencing, berms, and other structural components of the infiltration area should be inspected regularly to identify any safety concerns.

3.9.6 Winter Operation

Runoff should occur in winter only during periods of warmer weather (thaws). All piping should be designed to be empty unless flowing. The sump should be deep enough and covered to prevent freezing of the pump. If the sump freezes, turn off the pump until the ice melts.

3.9.7 Accessibility

Provide access, as required, to operate and maintain the system. Minimum access requirements are:

- screens
- collection pipe
- storage/setting basin
- sump
- pump
- conveyance & distribution pipes/channels
- splash pad
- infiltration area

3.9.8 Safety

Two primary hazards are associated with the VFS system: water and electricity (for pumped systems). Adequate protection should be provided to reduce the potential for accidents during and following construction. The Occupational Health and Safety Act and Regulations for Construction Projects, available from the Ontario Ministry of Labour, telephone 1-800-268-8013, provide information on the responsibilities of the constructor.

3.9.9 VFS System Inspection Sheet

Inspect the VFS system on a regular basis to ensure that all the components are functioning adequately. The following "VFS System Inspection Sheet" will provide a written record of inspection activities that have been undertaken.

Vegetative Filter Strip System Inspection Sheet

Item	Feature	Yes	No	N/A
Runoff Collection Area	Is manure being routinely removed?	☐	☐	☐
	Is upslope water being diverted and equipment (gutters, downspouts) well maintained?	☐	☐	☐
	Is area free of significant cracks?	☐	☐	☐
Collection/ Discharge Bay	Is collection/discharge bay being cleaned on a regular basis or at least after each major storm event?	☐	☐	☐
	Are screens being routinely cleaned?	☐	☐	☐
	Are screens in good working order?	☐	☐	☐
Perforated Riser Drainpipe	Is drainpipe in good working order?	☐	☐	☐
Orifice Plate	Does orifice plate allow for appropriate flow and is it free of solids and debris?	☐	☐	☐
Sump	Is sump routinely inspected for silt levels?	☐	☐	☐
	Is sump maintained in good working order?	☐	☐	☐
	Is lockable access hatch in good working order?	☐	☐	☐
	Is lockable access hatch locked when not in use?	☐	☐	☐
Siphon Device	Is siphon in good working order?	☐	☐	☐
Pump	If submersible, is appropriate water level maintained for required head and to prevent freezing of water in sump well?	☐	☐	☐
	Is pump clean and in good working order?	☐	☐	☐

Vegetative Filter Strip System Inspection Sheet				
Item	**Feature**	**Yes**	**No**	**N/A**
Conveyance Pipe	Are pipe and connections free of leaks?	☐	☐	☐
Conveyance Channel	Is channel appropriately lined?	☐	☐	☐
	Is channel appropriately maintained?	☐	☐	☐
Distribution Pipe	Is pipe free of leaks?	☐	☐	☐
	Are orifices clogged?	☐	☐	☐
	Is water being distributed uniformly through orifices?	☐	☐	☐
Distribution Channel	Is channel in good working order and routinely cleaned out?	☐	☐	☐
Erosion-proof Pad	Is pad in good working order, with no significant erosion problems or significant cracks or broken sections?	☐	☐	☐
	Is pad regularly inspected and relatively free of solids and debris?	☐	☐	☐
Infiltration Area	Is vegetation well maintained throughout the infiltration area?	☐	☐	☐
	Are spreaders inspected annually to confirm their level and functionality?	☐	☐	☐
	Is water ponding in infiltration area?	☐	☐	☐
	Is water being uniformly distributed throughout infiltration area?	☐	☐	☐

Inspected by: ______________________________

Date: ______________________________

4 Design Guide

This section provides a step-by-step process for designing a VFS system. Engineers and other professionals should find this Design Guide template very useful in designing VFS systems using either integrated storage/settling basins or external storage/settling basins. The numbering of the steps in the Design Guide matches the step numbers used in the Case Studies found in Section 5 of the manual.

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
	Establish opportunity and constraint map for infiltration area					
RUNOFF COLLECTION AREA						
1.1	Establish extent of area contributing runoff	Identify on a map the drainage patterns around proposed collection area; define all areas contributing surface runoff to the collection area; eliminate all clean water sources (e.g., roof drains), diverting clean flow and other waste flow (e.g., milking centre washwater, etc.).				
1.2	Define and measure extent of runoff collection area	Measure the area contributing water to the runoff collection area.		A = runoff collection area		m^2
1.3	Select runoff coefficient (see Section 3.1.3)	Surface of runoff collection area must be impervious. A concrete surface with a runoff coefficient of 0.95 is assumed. Select runoff coefficient that describes the imperviousness of the existing surface of the runoff collection area.		C = runoff coefficient	0.95	N/A
1.4	Storage/settling volume and peak discharge rate					
1.4.1 (a)	**Option 1**—Select design-storm event (see Section 3.1.4) for calculating the runoff storage/settling maximum basin volume requirements using the conservative method	Establish closest centre to farmstead from Table 6.1 and determine maximum storage/settling volume required.		Closest centre		
				V = storage settling volume		m^3
				A = runoff area		m^2
OR						
1.4.1 (b)	**Option 2**—Conservative maximum storage volume requirements based on a rainfall amount for a 25-year/24-hour storm event Use IDF Tables and Equation 3.1 to determine maximum storage volume	Calculate maximum storage volume.	$V_{max} = CaA$	V_{max} = maximum storage volume		m^3
				C = runoff coefficient	0.95	
				a = rainfall amount 25-year/24-hour storm event		m
				A = runoff area		m^2

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
1.4.2 (a)	**Option 1**—Minimum storage volume based on peak discharge rate of a 25-year storm return period for a 5-minute duration over a 15-minute period holding time	Establish closest centre to farmstead from Table 6.2. Establish peak discharge rate and minimum storage settling volume required from Table 6.2.		Closest centre		
				Peak discharge rate		m^3/s
				Minimum storage settling volume required		m^3
OR						
1.4.2 (b)	**Option 2**—Use IDF Tables and Equation 3.2 and 3.3 to determine peak discharge rate and minimum storage/settling volume required Calculate minimum storage/settling volume	Calculate peak discharge rate from runoff collection area (Equation 3.2).	$q_p = .0027CiA$	q_p = peak discharge rate		m^3/s
				C = runoff coefficient	0.95	
				i = rainfall rate 25-year/ 5-minute storm event		mm/h
				A = runoff collection area		ha
		Calculate minimum storage volume requirement with a minimum 15 minute (900 s) holding time (Equation 3.3).	$V_{min} = h_{tm} \times q_p$	V_{min} = minimum storage/settling volume requirement		m^3
				q_p = peak discharge		m^3/s
				h_{tm} = minimum holding time	900	s
STORAGE SETTLING BASIN						
2.1	Select storage type (see Section 3.2)	Determine preferred storage method: Integrated using containment wall or dedicated external basin.		Integrated		
				Dedicated External		
2.2	Develop integrated storage/settling basin	Use if runoff collection area is suitable for development of a watertight basin and sufficient volume can be generated using a containment wall around all or portion of runoff containment area.				

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
2.2.1 (a)	Determine maximum storage volume required	Volume is equal to the conservative maximum storage volume calculated in Step 1.4.1 (a) or Step 1.4.1 (b).		V_{max} = maximum storage volume		m^3
OR						
2.2.1 (b)	Determine minimum storage volume required	Minimum storage volume is calculated in Step 1.4.2(a) or Step 1.4.2(b).		V_{min} = minimum storage volume		m^3
2.2.2	Establish containment wall height					
2.2.2.1	Establish containment wall height assembly with consistent slope perpendicular to runoff flow to low side	Calculate containment wall height using Equation 3.4.	$h = \mathrm{sqrt}(2Vs/L)$	h = retaining wall height		m
				V = volume of storage required		m^3
				s = floor slope in the direction of flow		m/m
				L = runoff area length at right angles to flow		m
2.2.2.2	Establish containment wall height for runoff collection area that does not have one consistent slope to a low side	Methods available for calculating a volume based on a predicted elevation (top of wall) are the average end-area method, the planimeter method, and the average-depth method, or the creation of a 3-dimensional computer- generated terrain model.		h = retaining wall height		m
2.2.3	Establish total containment wall height	Establish final height required to accommodate runoff storage + 0.30 m for freeboard + 0.15 m for emergency overflow.	$h_t = h + 0.30 + 0.15$	h_t = total containment wall height		m
				h = retaining wall height		m

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
2.2.4	Calculate discharge rate from runoff collection area of integrated storage/settling basin with a holding time (h_{tm}) ranging from 4 to 10 hours (see Section 3.3.1)	Storage volume is equal to or greater than storage volume calculated in Step 2.2.1(a).	$q_{max} = V_{max}/h_{tm}$	q_{max} = discharge rate for maximum storage volume		m^3/s
				V_{max} = conservative maximum storage volume		m^3
				h_{tm} = holding time		s
		Storage volume is less than storage volume calculated in Step 2.2.1(a) but more than minimum storage volume from 25-year/5-minute storm event over a 15-minute period from Step 2.2.1(b).	$q_o = q_p[1.25 - (1500V/RA + 0.06)^{0.5}]$	q_o = rate of outflow when pipe flows full		m^3/s
				q_p = peak flow = discharge from runoff collection area		m^3/s
				V = available storage volume		ha-m
				R = return period runoff 25-year/24-hour		mm
				A = runoff collection area		ha
2.3	Develop dedicated external storage/settling basin					
2.3.1 (a)	Determine maximum storage volume required	Maximum storage volume is equal to the storage volume calculated in Step 2.2.1(a).		V_{max} = maximum storage volume		m^3
OR						
2.3.1 (b)	Determine minimum storage volume required	Minimum storage volume is equal to storage volume calculated in Step 1.4.2(a) or Step 1.4.2(b).		V_{min} = minimum storage volume		m^3
2.3.2	Establish storage volume of existing facility					

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
2.3.2.1	Establish volume capacity of existing storage facility	Method used will depend on design of existing storage facility. Subtract freeboard height (0.3 m) and emergency overflow height (0.15 m) before calculating maximum storage volume.		V = storage volume		m^3
		If volume capacity is greater than minimum volume required, then existing storage facility may be used to accommodate runoff water.		If Yes, proceed to next step		
				If No, existing facility is not suitable for development of external dedicated basin		
2.3.2.2	Establish operating parameters for existing storage facility	Establish the following:				
		• elevation of maximum storage volume				m
		• elevation of maximum storage volume minus freeboard (0.3 m) and emergency overflow height (0.15 m)				m
		• elevation of minimum storage volume				m
2.3.3	Establish new dedicated external basin					
2.3.3.1	Establish basin dimensions	Select minimum basin depth of 1.45 m (1.0 m liquid depth plus 0.3 m freeboard plus 0.15 m spillway depth).		Minimum basin depth	1.45	m
		Establish the basin length to width ratio of 3 to 1 to accommodate required minimum storage volume. Limit width of basin to between 3 m to 6 m to accommodate removal of solids using standard backhoe reach lengths.		Basin width		m
				Basin length		m
		Calculate basin depth for live storage from 2.3.1 (a) or 2.3.1 (b).		Basin depth for live storage		m
		Total basin depth is minimum basin depth plus basin depth for live storage.		Total basin depth		m

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
2.3.4	Calculate discharge rate from external storage/settling basin	Storage volume available is equal to or greater than storage volume calculated in Step 2.3.1(a).	$q_{max} = V_{max}/h_{tm}$	q_{max} = discharge rate for storage volume		m^3/s
				V_{max} = external storage volume		m^3
				h_{tm} = holding time		s
		Storage volume available is less than storage volume calculated in Step 2.3.1(a) but more than minimum storage volume from 25-year/5-minute storm event over a 15-minute period from Step 2.3.1(b).	$q_o = q_p[1.25 - (1500V/RA + 0.06)^{0.5}]$	q_o = rate of outflow when pipe flows full		m^3/s
				q_p = peak inflow = peak discharge from runoff collection area		m^3/s
				V = available storage volume		ha-m
				R = return period runoff 25-year/24-hour		mm
				A = runoff collection area		ha
RUNOFF COLLECTION/DISCHARGE BAY						
3.1	Establish collection point where runoff exits collection area to external basin	Establish collection/discharge bay dimension (length and width) to accommodate screens and drainpipe area for integrated storage basin scenario. Minimum width of collection/discharge bay opening to be 1.0 m. Collection/discharge bay height equal to containment wall height. Only screening of coarse materials may be done.		Width of collection/discharge bay		m
				Length of collection/discharge bay		m
				Height of collection/discharge bay		m
3.2	Establish screen configuration (if applicable)	Determine size of screens based on the opening dimension of the collection/discharge bay. Install handle on top of screen to ease removal. Allow for c-channel width when establishing screen width.		Screen width		m
				Screen height		m

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
3.3	Select screen material (if applicable)	Select material for construction of coarse, medium and fine screen.		Material		
		1. Coarse—vertical spacing of approx. 25 mm (1 in.)		Material		
		2. Medium—vertical spacing of approx. 10 mm (3/8 in.)		Material		
		3. Fine—vertical spacing of approx. 3.1 mm (1/8 in.)		Material		
3.4	Calculate orifice plate opening based on orifice discharge capacity	1. Integrated Storage—select discharge rate from Step 2.2.4.	$A = Q/[(C)(2gh)^{0.5}]$	A = orifice opening area		m^2
				Q = discharge rate from integrated storage		m^3/s
				C = orifice constant	0.61	
				g = acceleration due to gravity	9.8	m/s^2
				h = head on orifice		m
			$D = (4A/\pi)^{0.5}$	D = orifice diameter		m
				A = orifice opening area		m^2
		2. External Storage—select discharge rate from Step 2.3.4.	$A = Q/[(C)(2gh)^{0.5}]$	A = orifice opening area		m^2
				Q = discharge rate from external storage		m^3/s
				C = orifice constant	0.61	
				g = acceleration due to gravity	9.8	m/s^2
				h = head on orifice		m
			$D = (4A/\pi)^{0.5}$	D = orifice diameter		m
				A = orifice opening area		m^2

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
3.5	Calculate diameter of drainpipe	Select drainpipe to accommodate two times the discharge rate of the external storage/settling basin from Step 2.2.4 or 2.3.4.	$A = 2Q/[(C)(2gh)^{0.5}]$	A = area of drainpipe		m^2
				Q = discharge rate from external storage		m^3/s
				C = orifice constant	0.61	
				g = acceleration due to gravity	9.8	m/s^2
				h = head on orifice		m
			$D = (4A/\pi)^{0.5}$	D = diameter of drainpipe		m
				A = area of drainpipe		m^2
3.6	Determine the minimum open area in the perforated riser pipe	Use Equation 3.7 to determine the size of the open slot or hole area in the perforated riser pipe. Increase the open area by 25%.	$A = 1.25Q/[(C) \times (2gh)^{0.5}]$	A = minimum slot or hole area		m^2
				Q = orifice discharge capacity		m^3/s
				C = orifice constant	0.61	
				g = acceleration due to gravity	9.8	m/s^2
				h = head on orifice		m
		Choose individual slot size.		L = slot length		m
				W = slot width		m
		Calculate individual slot area.	Individual slot area = L x W			m^2
		OR				
		Choose individual hole diameter.		D = individual hole diameter		m
		Calculate individual hole area.	Individual hole area = $\pi D^2/4$			m^2
		Calculate number of slots or individual holes in perforated riser pipe.	No. of slots required = A/individual slot area			
			OR			
			No. of holes required = A/individual hole area			

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
3.7	Select sump	Select an appropriate size and type of sump. Maximum water depth in sump should be below frost line. Total sump depth equals frost-line depth plus depth to accommodate volume required by pump or siphon.		Sump volume (siphon/pump volume)		m^3
		Establish sump volume and dimensions.		Sump length		m
				Sump width		m
				Sump depth		m
				Material of sump		
3.8	Select siphon device	Contact a siphon device manufacturer to select the most appropriate gravity flow mechanism in the sump.				
	Note: Contact sump, siphon/pump manufacturer for sump volume recommendations					
CONVEYANCE PIPE						
4.1	Define target flow rate	Target conveyance pipe flow rate is 10% greater than storage/settling basin discharge rate from Step 2.2.4 or 2.3.4.		Orifice discharge rate from storage/settling basin increased by 10%		m^3/s
4.2	Establish minimum pipe/channel slope	Establish minimum pipe/channel slope based on Manning's Equation (Equation 3.9).	$A = Q/V$ $D = (4A/\pi)^{0.5}$ $R = D/4$ $S = (V_n/R^{2/3})^2$	A = area of pipe/channel		m^2
				Q = flow rate		m^3/s
				V = velocity of flow	0.6	m/s
				D = diameter of pipe		m
				R = hydraulic radius = area of water flow in pipe/channel divided by the wetted perimeter of pipe/channel; for circular pipe R = D/4		m
				S = minimum slope of pipe/channel		m/m
				n = Manning's n, PVC Pipe (smooth inner walls)	0.009	
				Earth channel (grass covered)	0.03	

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
4.3	Establish design variables for evaluation of conveyance system	Establish the inlet elevation of the conveyance pipe/channel from the sump/drainpipe (gravity flow with adjacent infiltration area).		E_{INLET} = Inlet elevation of conveyance pipe (from sump) or conveyance channel (from drainpipe)		m
		Establish conveyance pipe/channel run length from sump/drainpipe to top of infiltration area.		L = length of conveyance pipe/channel run		m
		Establish the elevation of the existing grade at top end of the candidate infiltration area.		$E_{EXISGRADE}$ = elevation at existing grade (at top end of infiltration area)		m
		Calculate outlet elevation of the conveyance pipe.		$E_{OUTLET} = E_{INLET} - (S)(L)$		m
				E_{OUTLET} = outlet elevation of conveyance pipe		m
				S = minimum slope of conveyance pipe (see Step 4.2)		m/m
				L = length of conveyance pipe run		m
		Compare conveyance pipe outlet elevation with elevation of existing grade at top end of infiltration area. See Step 4.4.		E_{OUTLET} = outlet elevation of conveyance pipe		m
				$E_{EXISGRADE}$ = elevation at existing grade at top end of infiltration area (see Step 4.4)		m
		Calculate elevation change between inlet elevation of conveyance pipe/channel from sump/drainpipe and elevation of existing grade at top end of infiltration area.		$E_{CHANGE} = E_{inlet} - E_{exisgrade}$ E_{CHANGE} = elevation change (represents lift for pump system or drop for gravity system)		m
4.4	Determine gravity or pump system	If the existing grade at the top end of the infiltration area is lower than the conveyance pipe outlet elevation calculated, e.g., positive elevation change, then gravity flow to the top end of the infiltration area is possible. Rerun Manning's equation to ensure that slope between inlet elevation of conveyance pipe and existing grade at the top of the infiltration area generates a minimum pipe flow velocity of 0.6 m/s.		Gravity flow		
		If the existing grade at the top of the infiltration area is higher than the conveyance pipe outlet elevation calculated, e.g., negative elevation change, then gravity flow to the top end of the infiltration area is not possible. A pump will be required to transfer the runoff to the top end of the infiltration area.		Pumped flow		

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
4.5	Determine target flow rate.	Target conveyance pipe flow rate is 10% greater than storage/settling basin discharge rate. See Step 4.1.		Orifice discharge rate from storage/settling basin		m^3/s
				Target conveyance pipe flow rate (10% greater than orifice discharge rate from storage/settling basin)		m^3/s
4.6	Determine total head losses between pump inlet and distribution pipe discharge	Determine head differential.		Difference in elevation between sump/drainpipe and existing grade at top end of infiltration area (see Step 4.3)		m
		To calculate pipe friction losses use Darcy –Weisbach Equation (Equation 3.8) with f = 0.020 or another equivalent method.	Friction losses = $f(L/D)(V^2/2g)$	Friction losses due to pipe run, including localized losses caused by pipe bends, valves, etc.		m
				f = friction factor	0.020	
				L = conveyance pipe length		m
				D = conveyance pipe diameter		m
				V = velocity of flow		m/s
				g = acceleration due to gravity	9.8	m/s^2
		Add pressure head of 0.9 m at the distribution pipe.		Distribution pipe pressure head	0.9	m
		Determine total head losses.	Total head losses = head differential plus pipe friction losses plus distribution pipe pressure head			m
4.7	Select type and size of pump	Select submersible sewage pump (preferably screw-induced flow) with automatic controls, capable of moving up to 24 mm solids. Obtain flow curves for selected pump and select the most efficient pump that will accommodate target conveyance pipe flow rate and head differential.		Manufacturer HP		

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
4.8	Determine pipe size required	The pipe size must be sufficient to convey the target discharge rate output. Check that pipe velocity does not exceed 1.5 m/s and friction losses are acceptable.		Conveyance pipe diameter		mm
4.9	Determine requirements for power and controls	Calculate distance from power source and effort required to power and automatically control pump.		Check pump requirements (110 V or 220 V, or other)		
				Contact consultant or electrical contractor for recommendations		
[illegible]						
5.1	Determine distribution pipe (or distribution channel) length	Determine actual distance pipe or distribution channel must distribute water from Step 6.7 (i.e., width of VFS).		Distribution channel to be gravel lined with geotextile fabric underneath		m
5.2	Select diameter (or width and depth) of distribution pipe or channel required	The distribution pipe (distribution channel) dimensions must be sufficient to convey the maximum siphon or pump output, or collection pipe orifice discharge capacity (gravity system) determined by flow and pipe velocity using Manning's Equation (Equation 3.9).	$D = 4[((Vn)/S^{0.5})^{1.5}]$	Distribution channel to be level on the downgradient side for even flow distribution along the length of the distribution channel		
				D = diameter of pipe		m
				V = velocity of flow		m/s
				n = Manning's n	0.009	
				S = slope of pipe		m/m
5.3	Determine capacity of orifice opening in distribution pipe	Use Equation 3.7; assume the head to be 0.90 m; assume C = 0.61.	$Q = (C)(A)(2gh)^{0.5}$	Q = orifice discharge capacity		m^3/s
				C = orifice constant	0.61	
				A = orifice area		m^2
				g = acceleration due to gravity	9.8	m/s^2
				h = head on orifice		m

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
5.4	Determine number of orifices to meet flow capacity being delivered	Use a 1.25 target distribution rate. Divide the target discharge rate for the distribution pipe by the orifice discharge rate determined in Step 5.3. Consider using a gated pipe with a minimum gate spacing of 0.6 m.	No. of orifice = 1.25 x target discharge rate/orifice discharge rate	No. of orifices		
			Orifice spacing = distribution pipe length/no. of orifices	Orifice spacing (centres)		m
INFILTRATION AREA						
6.1	Determine minimum infiltration area required based on saturated hydraulic conductivity (Stage 1)	Determine the saturated hydraulic conductivity for the infiltration area soil.	Minimum infiltration area = target flow rate (Step 4.5) ÷ saturated hydraulic conductivity	*In-situ* determination of saturated hydraulic conductivity required		m^2
6.2	Determine minimum infiltration area required based on liquid loading (Stage 2)	Use Table 3.3 to obtain highest normal monthly precipitation for closest station.		Maximum allowable liquid loading is 5 cm/week including rainfall		m/ month
		Calculate highest normal weekly precipitation (highest normal monthly precipitation divided by 4).		Closest rainfall station is provided in Table 3.3		m/ week
		Calculate outside paved yard weekly runoff volume.		Multiply the paved yard area by the highest normal weekly precipitation		m^3
		Calculate limiting precipitation amount per week on VFS.		The limiting precipitation amount per week is [5 cm minus highest normal weekly precipitation]		m
		Calculate minimum VFS area required.		The yard weekly runoff volume is divided by the limiting precipitation amount per week on VFS		m^2

Step	Description	Method/Design Parameter	Equation	Variables	Value	Units
6.3	Determine minimum infiltration area from Stage 1 (Step 6.1) and Stage 2 (Step 6.2)	Select larger infiltration area from Step 6.1 and Step 6.2.				m^2
6.4	Determine minimum length of infiltration area	Use Table 3.4 and VFS slope.				m
6.5	Determine minimum width of infiltration area	Use Equation 3.10.		Flow depth is 0.0127 m and flow velocity is found in Table 3.4		m
6.6	Calculate actual infiltration area dimensions	Select largest infiltration area from Stage 1 (Step 6.1) or Stage 2 (Step 6.2).		Minimum length of infiltration area comes from Step 6.4 (final width must be equal to or greater than distance calculated in Step 6.5)		m^2
6.7	Determine final dimensions of infiltration area	See Step 6.6 for final dimensions of infiltration area.		Final infiltration area dimensions	L = W = A =	m m m^2

5 Case Studies

5.1 Examples and Case Studies

The farm used in the case studies is located in Baltimore, Haldimand Township, Northumberland County, Ontario. It houses a small beef feedlot, which is partially covered. Figure 2.2 shows an aerial photograph of the farm.

Two alternative designs will be considered: Design #1—integrated, curb-wall, storage on the feedlot; and Design #2—external, dedicated storage basin with pumped flow of runoff to infiltration area.

The numbering of design steps is from the Design Guide found in Section 4.

5.1.1 Design #1—Design of VFS System (Integrated Storage)

The first step in the design of a VFS system for this farm was to confirm that the site conditions are suitable, with reference to Table 2.1 and Figure 2.2. A brief summary of the work required was prepared, to ensure that the project met the farmer's expectations.

For this case study, the following modifications are required to the existing systems:

- resurfacing the feedlot using an epoxy coating or concrete resurfacing to provide a watertight surface with a slope draining toward the collection point
- constructing curb walls around the feedlot, epoxy grouted to the surface, for a watertight seal
- constructing a road culvert for the conveyance piping

In addition, the following components of the system must be installed:

- collection and conveyance pipes
- VFS with distribution pipe and perimeter berms

Following is the decision process used to complete the system design.

Design #1 – Design of VFS System (Integrated Storage)

Step	Description	Method	Calculation
RUNOFF COLLECTION AREA			
1.1	Establish extent of area contributing runoff	Identify on a map the drainage patterns around proposed collection area; define all areas contributing surface runoff to the collection area; eliminate all clean water sources, diverting clean flow and other waste flow.	
1.2	Define and measure extent of runoff collection area	Measure the area contributing water to the runoff collection area.	Width = 20 m Length = 50 m Area = 20 m x 50 m = 1,000 m^2
1.3	Select runoff coefficient (see Section 3.1.3)	The surface of the runoff collection area must be non-porous. A concrete surface with a runoff coefficient of 0.95 is assumed.	C = 0.95
1.4	Determine storage/settling volume and peak discharge rate		
1.4.1 (a)	**Option 1**—Select design-storm event (see Section 3.1.4 for calculating the runoff storage/settling maximum basin volume requirements using the conservative method)	Establish closest centre to farmstead from Table 6.1 and determine storage/settling volume required.	Oshawa WPCP For an area of runoff collection A = 1,000 m^2, the maximum storage/settling volume $V_{max} = 69.1\ m^3$
OR			
1.4.1 (b)	**Option 2**—Use IDF Tables and Equation 3.1 to determine the maximum storage/settling volume	From IDF Tables determine 25-year/24-hour storm event for closest centre (Oshawa WPCP) and calculate maximum storage/settling volume.	For an area of runoff collection A = 1,000 m^2, the 25-year/24-hour storm event for Oshawa WPCP = 72.7 mm, the maximum storage/settling volume $V_{max} = (0.95)(72.7 \times 10^{-3}\ m)(1{,}000\ m^2) = 69.1 m^3$
1.4.2 (a)	**Option 1**—Select minimum storage volume based on peak discharge rate of a 25-year/5-minute storm event over a 15-minute holding time	Establish closest centre to farmstead from Table 6.2 and determine volume of runoff generated.	Oshawa WPCP For an area of runoff collection A = 1,000 m^2, the minimum storage settling volume $V_{min} = 31.7\ m^3$
	Calculate peak discharge rate	Calculate peak discharge by dividing volume obtained in Table 6.2 by holding time of 900 seconds.	$q_p = V_{min}/900 = 31.7/900 = 35 \times 10^{-3}\ m^3/s$
OR			
1.4.2 (b)	**Option 2**—Use IDF Tables and Equations 3.2 and 3.3 to determine peak discharge rate and minimum storage/settling volume	Use Equation 3.2. Rainfall intensity of 25-year/5-minute storm event for Oshawa WPCP is 137.4 mm/hr.	For an area of runoff collection A = 1,000 m^2, the peak discharge rate $q_p = (0.0027)(0.95)(137.4\ mm/hr)(0.1\ ha) = 35 \times 10^{-3}\ m^3/s$
	Calculate minimum storage/settling volume	Use Equation 3.3 to determine storage/settling volume.	The minimum storage/settling volume $V_{min} = h_{tm}\ q_p = (900\ sec)(35 \times 10^{-3}\ m^3/s) = 31.5\ m^3$ for a 15-minute settling time

Step	Description	Method	Calculation
STORAGE SETTLING BASIN			
2.1	Select storage type (see Section 3.2)	Determine preferred storage method: integrated using containment wall or dedicated external basin.	Integrated storage/settling basin
2.2	Develop integrated storage/settling basin	Use if runoff collection is suitable for development of a watertight basin and sufficient volume can be generated using a containment wall around all or portion of runoff containment area.	
2.2.1 (a)	Determine maximum storage volume required	Volume required is equal to the conservative maximum storage volume calculated in Step 1.4.1 (a) or Step 1.4.1 (b).	$V_{max} = 69.1\ m^3$
OR			
2.2.1 (b)	Determine minimum storage volume required	Minimum storage volume required is equal to volume calculated in Step 1.4.2 (a) or Step 1.4.2 (b).	$V_{min} = 31.7\ m^3$
2.2.2	Establish containment wall height		
2.2.2.1	Establish containment wall height assuming consistent slope perpendicular to runoff flow to a low side	Calculate containment wall height using Equation 3.4, assuming a consistent slope of 0.01 m/m and runoff collection area length perpendicular to the runoff flow.	$V = 69.1\ m^3$ $L = 50\ m$ $S = 0.01\ m/m$ $h = SQRT[(2 \times 69.1 \times 0.01/50)] = 0.17\ m$
2.2.3	Establish final height required to accommodate runoff storage + freeboard + emergency spillway	$h_t = h + 0.3 + 0.15$	$h_t = 0.17 + 0.3 + 0.15 = 0.62\ m$ (An integrated storage/settling basin can be accommodated for this application)
2.2.4	Calculate discharge rate from the runoff collection area for integrated storage/settling basin with a holding time ranging from 4 to 10 hours (see Section 3.3.1)	Establish closest centre to farmstead from Table 6.1 and determine discharge rate for a retention period of 4 hours.	Oshawa WPCP For an area of runoff collection $A = 1{,}000\ m^2$ and a retention period of 4 hours, $q_{max} = 4.8 \times 10^{-3}\ m^3/s$
		OR	
		Using storage volume (V_{max}) from Step 2.2.1(a), determine discharge rate for a retention period of 4 hours.	Discharge rate $q_{max} = 69.1 m^3/4 \times 60 \times 60\ sec = 4.8 \times 10^{-3}\ m^3/s$

Step	Description	Method	Calculation
RUNOFF COLLECTION/DISCHARGE BAY			
3.1	Establish collection/discharge bay dimension to accommodate screens and drainpipe area for integrated storage basin	Minimum width of collection/discharge bay opening = 1.0 m Length of collection/discharge bay opening Collection/discharge bay height equal to containment wall height	Width = 1.0 m Length = 2.0 m Height = 0.62 m
3.2	Establish screen configuration	Determine size of screens based on the opening measurements of the collection/discharge bay.	Width = 1.0 m Height = 0.62 m
3.3	Select screen material	Material: galvanized metal screen Coarse—vertical spacing of approx. 25 mm Medium—vertical spacing of approx. 10 mm Fine—vertical spacing of approx. 3 mm	Installation of screens to be vertical or at an angle of 60 degrees above the horizontal and sloped away from the flow
3.4	Calculate orifice plate opening based on orifice discharge capacity	Size the orifice opening to accommodate the maximum discharge rate of the integrated storage/settling basin (empty time of 4 hours) for the head equal to final containment wall height (use Table 3.1 or Equation 3.7). Use discharge rate from Step 2.2.4.	Q = 4.8 x 10^{-3} m^3/s h = 0.62 m Using Table 3.1 the orifice opening diameter D = 0.05 m Using Equation 3.7 orifice area A = 4.8 x 10^{-3} $m^3/s/[(0.61)(2 \times 9.8 \times 0.62)^{0.5}]$ = 2.25 x 10^{-3} m^2 and orifice diameter D = $(4 \times 2.25 \times 10^{-3}/\pi)^{0.5}$ = 0.054 m
3.5	Calculate diameter of drainpipe	Select drainpipe to accommodate two times the maximum flow rate through the orifice plate opening of the integrated storage/settling basin (empty time of 4 hours) for the head equal to final containment wall height (use Table 3.1 or Equation 3.7). Use discharge rate from Step 2.2.4.	Q = 4.8 x 10^{-3} m^3/s x 2 = 9.6 x 10^{-3} m^3/s h = 0.62 m Using Table 3.1 the orifice opening diameter D = 0.08 m Using Equation 3.7 A = $9.6 \times 10^{-3}/[(0.61)(2 \times 9.8 \times 0.62)^{0.5}]$ = 4.5 x 10^{-3} m^2 and orifice diameter D = $(4 \times 4.5 \times 10^{-3}/\pi)^{0.5}$ = 0.076 m Since the orifice diameter required is 0.08 m (approx), the drainpipe diameter will have to be 0.10 m diameter
3.6	Determine minimum open area in the perforated riser pipe	Use Equation 3.7 to determine the size of the open slot area. Increase the open area by 25%.	A = $4.8 \times 10^{-3}/[(0.61)(2 \times 9.8 \times 0.62)^{0.5}]$ = 2.25 x 10^{-3} x 1.25 = 2.8 x 10^{-3} m^2 = 28 cm^2 To get 28 cm^2 with 2 x 2 cm slots, it will be necessary to insert 7 slots
3.7	Select sump	Select appropriate size and type of sump. Maximum water depth in sump should be below frost line. Total sump depth = frost line depth + depth to accommodate volume required by pump. Contact sump and pump manufacturer for sump volume recommendations.	

Step	Description	Method	Calculation
CONVEYANCE PIPE			
4.1	Define target flow rate	Target conveyance pipe flow rate is 10% greater than storage/settling basin discharge rate from Step 2.2.4.	$Q = 4.8 \times 10^{-3} \times 1.10 = 5.3 \times 10^{-3}\ m^3/s$
4.2	Establish minimum pipe slope	Use Manning's Equation (Equation 3.9), assuming minimum velocity of 0.6 m/s and Manning's n coefficient = 0.009.	$A = Q/V = 5.3 \times 10^{-3}/0.6 = 8.8 \times 10^{-3}\ m^2$ $D = (4A/\pi)^{0.5} = (4 \times 8.8 \times 10^{-3}/\pi)^{0.5} = 0.11\ m$; Select 150 mm pipe $R = D/4 = 0.15/4 = 0.0375\ m$ $S = (Vn/R^{2/3})^2 = [0.6 \times 0.009/(0.0375)^{2/3}]^2 = 0.0023\ m/m$
4.3	Establish design variables for evaluation of conveyance system	Establish inlet elevation of the conveyance pipe from the sump.	Inlet elevation = 253 m
		Establish conveyance pipe run length from sump to top end of infiltration area.	Conveyance pipe run length = 260 m
		Establish the elevation of the existing grade at top end of the candidate infiltration area.	Elevation at top end of infiltration area = 270 m
		Calculate outlet elevation of conveyance pipe.	Conveyance pipe outlet elevation = 253 m – (0.0023 m/m x 260 m) = 252.4 m
		Compare conveyance pipe outlet elevation with elevation of existing grade at top end of infiltration area. See Step 4.4.	Conveyance pipe outlet elevation of 252.4 m vs. elevation of existing grade at top end of infiltration area of 270 m (see Step 4.4)
		Calculate elevation change between inlet elevation of conveyance pipe from sump/drainpipe and elevation of existing grade at top end of infiltration area.	Elevation change = 253 m – 270 m = –17 m, thus a rise in elevation of 17 m
4.4	Determine if gravity or pump system	If the existing grade at the top end of the infiltration area is higher than the conveyance pipe outlet elevation calculated, then gravity flow to the top end of the infiltration area is not possible.	See Step 4.3; a pump system must be used
4.5	Define target flow rate	See Step 4.1.	$Q = 4.8 \times 10^{-3} \times 1.10 = 5.3 \times 10^{-3}\ m^3/s$
4.6	Determine total head losses between pump inlet and distribution pipe discharge	Use Darcy-Weisbach Equation (Equation 3.8) with f = 0.020. For this case study it was assumed localized friction losses were negligible. Add the pressure head of 0.9 m at the distribution pipe.	Head differential (difference in elevation) = 17 m Friction losses = $f(L/D)(V^2/2g)$ $= 0.020\ (260/0.15)\ (0.6)^2/2 \times 9.81) = 0.64\ m$ Distribution pipe pressure head = 0.9 m Total head losses = 17 + 0.64 + 0.9 = 18.54 m

Step	Description	Method	Calculation
4.7	Select type and size of pump	Select submersible sewage pump (screw-induced flow preferred).	Obtain pump curves from manufacturer and select pump to accommodate target conveyance pipe flow rate and total head losses, i.e., 5.3×10^{-3} m^3/s @ total head losses of 18.54 m
4.8	Determine pipe size required	Recalculate pipe size based on pump selection and check that velocity does not exceed 1.5 m/s and friction losses are acceptable.	
4.9	Determine requirements for power and controls	Estimate distance from power source and effort required to power and automatically control pump.	Contact consultant or electrical contractor for recommendations.
DISTRIBUTION PIPE			
5.1	Determine distribution pipe length	Determine length of distribution pipe based on infiltration area width (calculated in Step 6.7).	Pipe length = 35 m (see Step 6.7)
5.2	Select diameter of distribution pipe required	Use Manning's Equation (Equation 3.9) with the assumption that the pipe slope is between 0.1% and 0.3% and the pipe will run full with minimum velocity of 0.6 m/s and n = 0.009.	Assume slope S = 0.3% = $0.3 \times 0.01 = 0.003$ m/m $D = 4[((Vn)/S^{0.5})^{1.5}]$ $= 4[((0.6 \times 0.009)/0.003^{0.5})^{1.5}]$ $= 0.124$ m Select 150 mm pipe
5.3	Determine capacity of orifice opening in distribution pipe	Use Equation 3.7 and assume the following: h = 0.9 m C = 0.61 Orifice diameter = 10 mm	$Q_{orifice} = CA(2gh)^{0.5}$ $= 0.61 \times \pi(0.01)^2/4$ $\times (2 \times 9.81 \times 0.9)^{0.5} = 0.2 \times 10^{-3}$ m^3/s
5.4	Determine number of orifices to meet flow capacity being delivered	Use a 1.25 target distribution volume. Divide the target discharge rate for the distribution pipe by the orifice discharge rate for each orifice opening as determined in Step 5.3.	$Q = 4.8 \times 10^{-3} \times 1.10 \times 1.25$ $= 6.6 \times 10^{-3}$ m^3/s No. of orifices = $6.6 \times 10^{-3}/0.2 \times 10^{-3}$ = 33 orifices Select 34 orifices Orifice spacing = distribution pipe length (Step 5.1)/no of orifices = 35 m/34 = 1.03 m Space orifices on 1.03 m centres

Step	Description	Method	Calculation
INFILTRATION AREA			
6.1	Determine minimum infiltration area required based on saturated hydraulic conductivity (Stage 1)	An *in-situ* determination of saturated hydraulic conductivity was performed and a value of 0.3168 m/day was obtained. Table 6.3 can also be used after soil texture has been determined.	$Q = 4.8 \times 10^{-3} \times 1.10 = 5.3 \times 10^{-3}$ m^3/s = 458 m^3/day A = 458 m^3/day/0.3168 m/day = 1,445 m^2
6.2	Determine minimum infiltration area required based on liquid loading (Stage 2)	Use Table 3.3 to obtain the highest normal monthly precipitation for the closest station.	Highest normal monthly precipitation for closest centre (Trenton Airport) = 91.2 mm = 0.0912 m/month
		Calculate highest normal weekly precipitation (highest normal monthly precipitation/4).	Highest normal weekly precipitation = 0.0912/4 = 22.8×10^{-3} m/week
		Calculate outside paved yard weekly runoff volume. Paved yard has area of 1,000 m^2.	Paved yard weekly runoff volume = 1,000 $m^2 \times 22.8 \times 10^{-3}$ = 22.8 m^3
		Calculate limiting precipitation amount per week on VFS. Maximum allowable liquid loading is 0.05 m.	Limiting precipitation amount/week on VFS = 0.05 m – (22.8×10^{-3}) = 27.2×10^{-3} m
		Calculate minimum VFS area required based on paved yard weekly runoff and limiting amount of precipitation/week on VFS area.	Minimum VFS area required = 22.8 m^3/27.2×10^{-3} m = 838 m^2
6.3	Determine minimum infiltration area from Stage 1 (Step 6.1) and Stage 2 (Step 6.2)	See Step 6.1 and Step 6.2. Select larger infiltration area from Step 6.1 and Step 6.2.	Minimum infiltration area from Stage 1 (Step 6.1) is 1,445 m^2
6.4	Determine minimum length of infiltration area	VFS slope is 4% (see Table 3.4).	For slope of 4% the VFS length is 41 m
6.5	Determine minimum width of infiltration area	Use Equation 3.10 (see Table 3.4).	Flow depth 1.27×10^{-2}m Velocity 4.54×10^{-2} m/s W = 5.3×10^{-3} m^3/s/(1.27×10^{-2} m x 4.54×10^{-2} m/s) = 9.2 m
6.6	Calculate actual infiltration area dimensions	Select largest infiltration area determined from Stage 1 (Step 6.1), hydraulic conductivity measurement or Stage 2 (Step 6.2), liquid loading limit. Use minimum length (Step 6.4) in determining final dimensions of infiltration area. Ensure that final width exceeds minimum width (see Step 6.5).	Largest area results from Step 6.1 of 1,445 m^2; therefore, A = 1,445 m^2 Step 6.1 L = 41 m Step 6.4 W = A/L = 1,445 m^2/41 m = 35.2 m > 9.2 m
6.7	Determine final dimensions of infiltration area	Final infiltration area dimensions.	Length = 41 m Width = 35.2 m Area = 1,445 m^2

5.1.2 Design #2—Design of VFS System (External Storage)

For Design #2, utilizing an existing external storage basin, the following modifications are required for the existing system:

- resurfacing the feedlot to provide a watertight surface with a slope draining toward the collection point
- constructing a road culvert for the conveyance piping

In addition, the following components of the system must be installed:

- external settling/storage basin (existing) and sump with pump
- collection and conveyance pipes
- VFS with distribution pipe and perimeter berms

Following is an outline of the decision process used to complete the system design.

Design #2 – Design of VFS System (External Storage)

Step	Description	Method	Calculation
RUNOFF COLLECTION AREA			
1.1	Establish extent of area contributing runoff	Identify on a map the drainage patterns around proposed collection area; define all areas contributing surface runoff to the collection area; eliminate all clean water sources, diverting clean flow and other waste flow.	
1.2	Define and measure extent of runoff collection area	Measure the area contributing water to the runoff collection area.	Width = 20 m Length = 50 m Area = 20 m x 50 m = 1,000 m^2
1.3	Select runoff coefficient (see Section 3.1.3)	The surface of the runoff collection area must be non-porous. A concrete surface with a runoff coefficient of 0.95 is assumed.	$C = 0.95$
1.4	Determine storage/settling volume and peak discharge rate		
1.4.1 (a)	**Option 1**—Select design-storm event (see Section 3.1.4 for calculating the runoff storage/settling maximum basin volume requirements using the conservative method)	Establish closest centre to farmstead from Table 6.1 and determine storage/settling volume required.	Oshawa WPCP For an area of runoff collection A = 1,000 m^2, the maximum storage/settling volume $V_{max} = 69.1\ m^3$
OR			
1.4.1 (b)	**Option 2**—Use IDF Tables and Equation 3.1 to determine the maximum storage/settling volume	From IDF Tables determine 25-year/24-hour storm event for closest centre (Oshawa WPCP) and calculate maximum storage/settling volume.	For an area of runoff collection A = 1,000 m^2, the 25-yr/24-hr storm event for Oshawa WPCP = 72.7 mm, the maximum storage/settling volume $V_{max} = (0.95)(72.7 \times 10^{-3}\ m)(1,000\ m^2) = 69.1 m^3$
1.4.2 (a)	**Option 1**—Select minimum storage volume based on peak discharge rate of a 25-year storm with 5-minute duration and 15-minute holding time (see Section 3.1.4 for calculating the storage/settling basin volume requirements using the rational method)	Establish closest centre to farmstead from Table 6.2 and determine volume of runoff generated.	Oshawa WPCP For an area of runoff collection A = 1,000 m^2, the minimum storage settling volume $V_{min} = 31.7\ m^3$
		Calculate peak discharge by dividing the volume obtained in Table 6.2 by the holding time of 900 seconds.	$q_p = V_{min}/900 = 31.7/900 = 35 \times 10^{-3}\ m^3/s$
OR			
1.4.2 (b)	**Option 2**—Use IDF Tables and Equations 3.2 and 3.3 to determine peak discharge rate and minimum storage/settling volume Calculate minimum storage/settling volume	Use Equation 3.2. Rainfall intensity of 25-year/5-minute storm event for Oshawa WPCP is 137.4 mm/hr.	For an area of runoff collection A = 1,000 m^2, the peak discharge rate $q_p = (0.0027)(0.95)(137.4\ mm/hr)(0.1\ ha) = 35 \times 10^{-3}\ m^3/s$
		Use Equation 3.3 to determine minimum storage volume.	The minimum storage/settling volume $V_{min} = h_{tm}\ q_p = (900\ sec)(35 \times 10^{-3}\ m^3/s) = 31.5\ m^3$ for a 15-minute settling time

Step	Description	Method	Calculation
STORAGE SETTLING BASIN			
2.1	Select storage type (see Section 3.2)	Determine preferred storage method: integrated using containment wall or dedicated external basin.	Dedicated external basin
2.3	Dedicated external storage/settling basin development		
2.3.1 (a)	Determine maximum storage volume required	Volume is equal to the maximum storage volume calculated in Step 1.4.1 (a) or Step 1.4.1 (b).	$V_{max} = 69.1\ m^3$
OR			
2.3.1 (b)	Determine minimum storage volume required	Minimum storage volume required is equal to volume calculated in Step 1.4.2 (a) or Step 1.4.2 (b).	$V_{min} = 31.7\ m^3$
2.3.2	Establish storage volume of existing facility		
2.3.2.1	Establish volume capacity of existing storage facility	Subtract freeboard height and emergency overflow height before calculating maximum storage volume.	Existing storage basin dimensions: depth = 1.5 m, diameter = 7 m $V = [\pi(7)^2/4] \times (1.5 - 0.3 - 0.15) = 40.4\ m^3$ Since volume capacity is greater than minimum storage volume (31.7 m^3) required, the existing basin can be used to accommodate runoff water; however, existing storage does not have capacity to hold 25-yr/24-hr storm (69.1 m^3).
2.3.2.2	Establish operating parameters for existing storage facility	Establish elevation of maximum storage volume.	Elev = 1.50 m
		Establish elevation of maximum storage volume minus freeboard and emergency overflow height.	Elev = 1.05 m
		Establish elevation of minimum storage volume.	Elev = 0.82 m (assumed)
2.3.4	Calculate discharge rate from external storage/settling basin	Use routing equation (Equation 3.6) since storage volume available is less than storage volume calculated in Step 2.3.1(a) but more than minimum storage volume from 25-year/5-minute storm event over a 15-minute period from Step 2.3.1(b).	$q_p = 35 \times 10^{-3}\ m^3/s$ $V = 40.4\ m^3 = 4.04 \times 10^{-3}$ ha-m R = 72.7 mm (IDF Table – Oshawa) $A = 1{,}000\ m^2 = 0.1$ ha $q_o = 35 \times 10^{-3} [1.25 - (1500 \times 4.04 \times 10^{-3}/72.7 \times 0.1 + 0.06)^{0.5}] = 10.7 \times 10^{-3}\ m^3/s$

Step	Description	Method	Calculation
RUNOFF DISCHARGE SYSTEM COLLECTION BAY			
3.1	Establish collection point where runoff exits collection area to external basin	Select screening device to prevent coarse materials from entering external basin.	Wood picket fence screening device to have 3/4" spacing between 2" x 6" vertical pickets
3.4	Calculate orifice plate opening based on orifice discharge capacity	Size the orifice opening to accommodate the maximum discharge rate of the external storage/settling basin for head equal to depth of liquid on orifice plate (Use Table 3.1 or Equation 3.7). Use discharge rate from Step 2.3.4.	$Q = 10.7 \times 10^{-3}$ m^3/s $h = 1.05 - 0.82 = 0.23$ m Using Table 3.1 the orifice opening diameter $D = 0.11$ m Using Equation 3.7 Orifice area $A = 10.7 \times 10^{-3}$ m^3/s/ $[(0.61)(2 \times 9.8 \times 0.23)^{0.5}]$ $= 8.26 \times 10^{-3}$ m^2 and orifice diameter $D = (4 \times 8.26 \times 10^{-3}/\pi)^{0.5}$ $= 0.10$ m
3.5	Calculate diameter of drainpipe	Select drainpipe to accommodate two times the discharge rate of the external storage/settling basin (Use Table 3.1 or Equation 3.7). Use discharge rate from Step 2.3.4.	$Q = 10.7 \times 10^{-3}$ m^3/s $\times 2 =$ 21.4×10^{-3} m^3/s $h = 1.05 - 0.82 = 0.23$ m Using Table 3.1 the orifice opening diameter $D = 0.14$ m Using Equation 3.7 $A = 21.4 \times 10^{-3}$ m^3/s/ $[(0.61)(2 \times 9.8 \times 0.23)^{0.5}]$ $= 16.5 \times 10^{-3}$ m^2 and orifice diameter $D = (4 \times 16.5 \times 10^{-3}/\pi)^{0.5}$ $= 0.14$ m
3.6	Determine minimum open area in perforated riser pipe	Use Equation 3.7 to determine the size of the open slot area. Increase the open area by 25%.	$A = 10.7 \times 10^{-3}/[(0.61)(2 \times 9.8 \times 0.23)^{0.5}]$ $= 8.26 \times 10^{-3} \times 1.25 = 10.3 \times 10^{-3}$ m^2 $= 103$ cm^2 To get 103 cm^2 with 2 x 2 cm slots, it will be necessary to insert 26 slots
3.7	Select sump	Select appropriate size and type of sump. Maximum water depth in sump should be below frost line. Total sump depth = frost line depth + depth to accommodate volume required by pump or siphon device. Contact sump and siphon device or pump manufacturer for sump volume recommendations.	
3.8	Select siphon device	Contact a siphon device manufacturer to select the most appropriate mechanism for gravity flow (e.g., Flout™)[2].	

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[2] The use of trademarks does not imply endorsement by OMAFRA, MOE, and CH2M HILL Canada Limited.

Step	Description	Method	Calculation
CONVEYANCE PIPE			
4.1	Define target flow rate	Target conveyance pipe flow rate is 10% greater than storage/settling basin discharge rate from Step 2.3.4.	$Q = 10.7 \times 10^{-3} \times 1.10$ $= 11.8 \times 10^{-3}$ m^3/s
4.2	Establish minimum pipe slope	Use Manning's Equation (Equation 3.9), assuming minimum velocity of 0.6 m/s and Manning's n coefficient = 0.009.	$A = Q/V = 11.8 \times 10^{-3}/0.6 = 0.020$ m^2 $D = (4 \times 0.020/\pi)^{0.5} = 0.16$ m; select 200 mm pipe $R = D/4 = 0.2/4 = 0.05$ m $S = [0.6 \times 0.009/(0.05)^{2/3}]^2$ $= 0.0016$ m/m
4.3	Establish design variables for evaluation of conveyance system	Establish inlet elevation of the conveyance pipe from the sump	Inlet elevation = 253 m
		Establish conveyance pipe run length from sump to top of infiltration area.	Conveyance pipe run length = 260 m
		Establish the elevation of the existing grade at top end of the candidate infiltration area.	Elevation at top end of infiltration area = 270 m
		Calculate outlet elevation of conveyance pipe.	Conveyance pipe outlet elevation = 253 m – (0.0016 m/m x 260 m) = 252.6 m
		Compare conveyance pipe outlet elevation with elevation of existing grade at top end of infiltration area (see Step 4.4).	Conveyance pipe outlet elevation of 252.6 m vs. elevation of existing grade at top end of infiltration area of 270 m (see Step 4.4)
		Calculate elevation change between inlet elevation of conveyance pipe from sump/drainpipe and elevation of existing grade at top end of infiltration area.	Elevation change = 253 m – 270 m = –17 m, thus a rise in elevation of 17 m for pump system
4.4	Determine if gravity or pump system	If the existing grade at the top end of the infiltration area is higher than the conveyance pipe outlet elevation calculated, then gravity flow to the top end of the infiltration area is not possible.	See Step 4.3 (a pump system must be used)
4.5	Define target flow rate	See Step 4.1.	$Q = 10.7 \times 10^{-3} \times 1.10$ $= 11.8 \times 10^{-3}$ m^3/s
4.6	Determine total head losses between pump inlet and distribution pipe discharge	Use Darcy-Weisbach Equation (Equation 3.8) with f = 0.020. For this case study it was assumed localized friction losses were negligible. Add the pressure head of 0.9 m at the distribution pipe.	Head differential (difference in elevation) = 17 m Friction losses = $f(L/D)(V^2/2g)$ $= 0.020\ (260/0.15)\ (0.6)^2/2 \times 9.81 = 0.64$ m Distribution pipe pressure head = 0.9 m Total head losses = 17 + 0.64 + 0.9 = 18.54 m

Step	Description	Method	Calculation
4.7	Select type and size of pump	Select submersible sewage pump (screw-induced flow preferred).	Obtain pump curves from manufacturer and select pump to accommodate target conveyance pipe flow rate and total head losses, i.e., 11.8×10^{-3} m^3/s at total head losses of 18.54 m
4.8	Determine pipe size required	Recalculate pipe size based on pump selection and check that velocity does not exceed 1.5 m/s and friction losses are acceptable.	
4.9	Determine requirements for power and controls	Estimate distance from power source and effort required to power and automatically control pump.	Contact consultant or electrical contractor for recommendations.
DISTRIBUTION PIPE			
5.1	Determine distribution pipe length	Determine length of distribution pipe based on infiltration area width (calculated in Step 6.7).	Pipe length = 78.5 m (see Step 6.7)
5.2	Select diameter of distribution pipe required	Use Manning's Equation (Equation 3.9) with the assumption that the pipe slope is between 0.1% and 0.3% and the pipe will run full with minimum velocity of 0.6 m/s and n = 0.009.	Assume slope S = 0.3% = 0.3 x 0.01 = 0.003 m/m $D = 4[((Vn)/S^{0.5})^{1.5}]$ $= 4[((0.6 \times 0.009)/0.003^{0.5})^{1.5}]$ = 0.124 m Select 150 mm pipe
5.3	Determine capacity of orifice opening in distribution pipe	Use Equation 3.7 and assume the following: h = 0.9 m C = 0.61 Orifice diameter = 20 mm	$Q_{orifice} = 0.61 \times \pi(0.02)^2/4 \times (2 \times 9.8 \times 0.9)^{0.5} = 0.8 \times 10^{-3}$ m^3/s
5.4	Determine number of orifices to meet flow capacity being delivered	Use a 1.25 target distribution volume. Divide the target discharge rate for the distribution pipe by the orifice discharge rate for each orifice opening as determined in Step 5.3.	$Q = 11.8 \times 10^{-3} \times 1.25 = 0.015$ m^3/s No. of orifices = $0.015/0.8 \times 10^{-3}$ = 19 orifices Select 20 orifices Orifice spacing = distribution pipe length (Step 5.1)/no. of orifices = 78.5 m/20 = 3.93 m Space orifices 78.5 m/20 = 3.93 m on centres

Step	Description	Method	Calculation
INFILTRATION AREA			
6.1	Determine minimum infiltration area required based on saturated hydraulic conductivity (Stage 1)	An *in-situ* determination of saturated hydraulic conductivity was performed and a value of 0.3168 m/day was obtained.	$Q = (10.7 \times 10^{-3}) \times 1.10$ $= 11.8 \times 10^{-3}$ $m^3/s = 1,020$ m^3/day $A = 1,020/0.3168 = 3,220$ m^2
6.2	Determine minimum infiltration area required based on liquid loading (Stage 2)	Use Table 3.3 to obtain the highest normal monthly precipitation for the closest station.	Highest normal monthly precipitation for closest centre (Trenton Airport) = 91.2 mm = 0.0912 m/month
		Calculate highest normal weekly precipitation (highest normal monthly precipitation/4).	Highest normal weekly precipitation = $0.0912/4 = 22.8 \times 10^{-3}$ m/week
		Calculate outside paved yard weekly runoff volume. Paved yard has area of 1,000 m^2.	Paved yard weekly runoff volume = 1,000 m^2 x (22.8×10^{-3}) = 22.8 m^3
		Calculate limiting precipitation amount per week on VFS. Maximum allowable liquid loading is 0.05 m per week.	Limiting precipitation amount/week on VFS = 0.05 m – (22.8×10^{-3}) $= 27.2 \times 10^{-3}$ m
		Calculate minimum VFS area required, based on paved yard weekly runoff and limiting amount of precipitation/week on VFS area.	Minimum VFS area required = 22.8 m^3/27.2×10^{-3} m = 838 m^2
6.3	Determine minimum infiltration area from Stage 1 (Step 6.1) and Stage 2 (Step 6.2)	See Step 6.1 and Step 6.2. Select larger infiltration area from Step 6.1 and Step 6.2.	Minimum infiltration area from Stage 1 (Step 6.1) is 3,220 m^2
6.4	Determine minimum length of infiltration area	VFS slope is 4% (see Table 3.4).	For slope of 4% the VFS length is 41 m
6.5	Determine minimum width of infiltration area	Use Equation 3.10 (see Table 3.4).	Flow depth 1.27×10^{-2} m Velocity 4.54×10^{-2} m/s $W = 11.8 \times 10^{-3}$ $m^3/s/(1.27 \times 10^{-2}$ m x 4.54×10^{-2} m/s) = 20.5 m
6.6	Calculate actual infiltration area dimensions	Select largest infiltration area determined from Stage 1 (Step 6.1), hydraulic conductivity measurement or Stage 2 (Step 6.2), liquid loading limit. Use minimum length (Step 6.4) in determining final dimensions of infiltration area. Ensure that final width exceeds minimum width (see Step 6.5).	Largest infiltration area results from Step 6.1 of 3,220 m^2; therefore, A = 3,220 m^2 (Step 6.1) L = 41 m (Step 6.4) W = A/L = 3,220 m^2/41 m = 78.5 m > 20.5 m
6.7	Determine final dimensions of infiltration area	Final infiltration area dimensions.	Length = 41 m Width = 78.5 m Area = 3,220 m^2

5.2 Alternative Runoff Treatment

Should the farmer decide that a VFS system is not suitable for his or her operation, alternatives for managing the runoff could include:

- extending roof to cover the feedlot and manure storage area completely
- collecting the runoff and storing it for subsequent land application (volume to provide 240 days storage required)

If land application of runoff is limited by the nutrient content of the runoff, then the following alternatives may be considered for treatment:

- constructed wetland
- vegetative infiltration basin (VIB)

These two alternatives rely on soil and plant properties for filtering nutrients and other contaminants from the runoff water. In the VIB system tile drains collect the infiltrated water and deliver the treated sub-surface discharge to a storage tank or to an additional treatment unit (e.g., constructed wetland or VFS system).

6 Design Tables

This section of the manual contains the following tables:

- **Table 6.1**

  Maximum Runoff Storage/Settling Volume Using Conservative Method (m^3), 25-year, 24-hour Storm, Holding 100%

- **Table 6.2**

  Minimum Storage/Settling Volume Required (m^3) and Peak Discharge Rate (m^3/s) Using Rational Method 25-year, 5-minute Peak Discharge Rate

- **Table 6.3**

  Infiltration Area Required Based on Saturated Hydraulic Conductivity of Soil Texture Classes

Table 6.1 Maximum runoff storage/settling volume using conservative method (m³), 25-year, 24-hour storm, holding 100%

Area of runoff collection area (m²)	Storage/ Settling Volume*	Thunder Bay Airport						
		Discharge Rate for following Retention Periods						
		4 hr	**5 hr**	**6 hr**	**7 hr**	**8 hr**	**9 hr**	**10 hr**
	(m³)	**(m³/s)**	**(m³/s)**	**(m³/s)**	**(m³/s)**	**(m³/s)**	**(m³/s)**	**(m³/s)**
	(gal)	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***
100	9.39	6.52E-04	5.21E-04	4.35E-04	3.72E-04	3.26E-04	2.90E-04	2.61E-04
	2,479.50	*10.33*	*8.26*	*6.89*	*5.90*	*5.17*	*4.59*	*4.13*
200	18.77	1.30E-03	1.04E-03	8.69E-04	7.45E-04	6.52E-04	5.79E-04	5.21E-04
	4,959.00	*20.66*	*16.53*	*13.77*	*11.81*	*10.33*	*9.18*	*8.26*
300	28.16	1.96E-03	1.56E-03	1.30E-03	1.12E-03	9.78E-04	8.69E-04	7.82E-04
	7,438.50	*30.99*	*24.79*	*20.66*	*17.71*	*15.50*	*13.77*	*12.40*
400	37.54	2.61E-03	2.09E-03	1.74E-03	1.49E-03	1.30E-03	1.16E-03	1.04E-03
	9,918.00	*41.32*	*33.06*	*27.55*	*23.61*	*20.66*	*18.37*	*16.53*
500	46.93	3.26E-03	2.61E-03	2.17E-03	1.86E-03	1.63E-03	1.45E-03	1.30E-03
	12,397.50	*51.66*	*41.32*	*34.44*	*29.52*	*25.83*	*22.96*	*20.66*
600	56.32	3.91E-03	3.13E-03	2.61E-03	2.23E-03	1.96E-03	1.74E-03	1.56E-03
	14,877.00	*61.99*	*49.59*	*41.32*	*35.42*	*30.99*	*27.55*	*24.79*
700	65.70	4.56E-03	3.65E-03	3.04E-03	2.61E-03	2.28E-03	2.03E-03	1.83E-03
	17,356.50	*72.32*	*57.85*	*48.21*	*41.32*	*36.16*	*32.14*	*28.93*
800	75.09	5.21E-03	4.17E-03	3.48E-03	2.98E-03	2.61E-03	2.32E-03	2.09E-03
	19,836.00	*82.65*	*66.12*	*55.10*	*47.23*	*41.32*	*36.73*	*33.06*
900	84.47	5.87E-03	4.69E-03	3.91E-03	3.35E-03	2.93E-03	2.61E-03	2.35E-03
	22,315.50	*92.98*	*74.38*	*61.99*	*53.13*	*46.49*	*41.32*	*37.19*
1,000	93.86	6.52E-03	5.21E-03	4.35E-03	3.72E-03	3.26E-03	2.90E-03	2.61E-03
	24,795.00	*103.31*	*82.65*	*68.87*	*59.04*	*51.66*	*45.92*	*41.32*
1,500	140.79	9.78E-03	7.82E-03	6.52E-03	5.59E-03	4.89E-03	4.35E-03	3.91E-03
	37,192.49	*154.97*	*123.97*	*103.31*	*88.55*	*77.48*	*68.87*	*61.99*
2,000	187.72	0.01	0.01	8.69E-03	7.45E-03	6.52E-03	5.79E-03	5.21E-03
	49,589.99	*206.62*	*165.30*	*137.75*	*118.07*	*103.31*	*91.83*	*82.65*
2,500	234.65	0.02	0.01	0.01	9.31E-03	8.15E-03	7.24E-03	6.52E-03
	61,987.49	*258.28*	*206.62*	*172.19*	*147.59*	*129.14*	*114.79*	*103.31*
3,000	281.58	0.02	0.02	0.01	0.01	9.78E-03	8.69E-03	7.82E-03
	74,384.99	*309.94*	*247.95*	*206.62*	*177.11*	*154.97*	*137.75*	*123.97*
3,500	328.51	0.02	0.02	0.02	0.01	0.01	0.01	9.13E-03
	86,782.49	*361.59*	*289.27*	*241.06*	*206.62*	*180.80*	*160.71*	*144.64*
4,000	375.44	0.03	0.02	0.02	0.01	0.01	0.01	0.01
	99,179.98	*413.25*	*330.60*	*275.50*	*236.14*	*206.62*	*183.67*	*165.30*
4,500	422.37	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	111,577.48	*464.91*	*371.92*	*309.94*	*265.66*	*232.45*	*206.62*	*185.96*
5,000	469.30	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	123,974.98	*516.56*	*413.25*	*344.37*	*295.18*	*258.28*	*229.58*	*206.62*
5,500	516.23	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	136,372.48	*568.22*	*454.57*	*378.81*	*324.70*	*284.11*	*252.54*	*227.29*
6,000	563.16	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	148,769.98	*619.87*	*495.90*	*413.25*	*354.21*	*309.94*	*275.50*	*247.95*
6,500	610.09	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	161,167.48	*671.53*	*537.22*	*447.69*	*383.73*	*335.77*	*298.46*	*268.61*
7,000	657.02	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	173,564.97	*723.19*	*578.55*	*482.12*	*413.25*	*361.59*	*321.42*	*289.27*
7,500	703.95	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	185,962.47	*774.84*	*619.87*	*516.56*	*442.77*	*387.42*	*344.37*	*309.94*
8,000	750.88	0.05	0.04	0.03	0.03	0.03	0.02	0.02
	198,359.97	*826.50*	*661.20*	*551.00*	*472.29*	*413.25*	*367.33*	*330.60*
8,500	797.81	0.06	0.04	0.04	0.03	0.03	0.02	0.02
	210,757.47	*878.16*	*702.52*	*585.44*	*501.80*	*439.08*	*390.29*	*351.26*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."
Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Sault Ste. Marie Airport						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	8.47	5.88E-04	4.71E-04	3.92E-04	3.36E-04	2.94E-04	2.62E-04	2.35E-04
	2,238.58	*9.33*	*7.46*	*6.22*	*5.33*	*4.66*	*4.15*	*3.73*
200	16.95	1.18E-03	9.42E-04	7.85E-04	6.73E-04	5.88E-04	5.23E-04	4.71E-04
	4,477.15	*18.65*	*14.92*	*12.44*	*10.66*	*9.33*	*8.29*	*7.46*
300	25.42	1.77E-03	1.41E-03	1.18E-03	1.01E-03	8.83E-04	7.85E-04	7.06E-04
	6,715.73	*27.98*	*22.39*	*18.65*	*15.99*	*13.99*	*12.44*	*11.19*
400	33.90	2.35E-03	1.88E-03	1.57E-03	1.35E-03	1.18E-03	1.05E-03	9.42E-04
	8,954.31	*37.31*	*29.85*	*24.87*	*21.32*	*18.65*	*16.58*	*14.92*
500	42.37	2.94E-03	2.35E-03	1.96E-03	1.68E-03	1.47E-03	1.31E-03	1.18E-03
	11,192.88	*46.64*	*37.31*	*31.09*	*26.65*	*23.32*	*20.73*	*18.65*
600	50.84	3.53E-03	2.82E-03	2.35E-03	2.02E-03	1.77E-03	1.57E-03	1.41E-03
	13,431.46	*55.96*	*44.77*	*37.31*	*31.98*	*27.98*	*24.87*	*22.39*
700	59.32	4.12E-03	3.30E-03	2.75E-03	2.35E-03	2.06E-03	1.83E-03	1.65E-03
	15,670.04	*65.29*	*52.23*	*43.53*	*37.31*	*32.65*	*29.02*	*26.12*
800	67.79	4.71E-03	3.77E-03	3.14E-03	2.69E-03	2.35E-03	2.09E-03	1.88E-03
	17,908.61	*74.62*	*59.70*	*49.75*	*42.64*	*37.31*	*33.16*	*29.85*
900	76.27	5.30E-03	4.24E-03	3.53E-03	3.03E-03	2.65E-03	2.35E-03	2.12E-03
	20,147.19	*83.95*	*67.16*	*55.96*	*47.97*	*41.97*	*37.31*	*33.58*
1,000	84.74	5.88E-03	4.71E-03	3.92E-03	3.36E-03	2.94E-03	2.62E-03	2.35E-03
	22,385.77	*93.27*	*74.62*	*62.18*	*53.30*	*46.64*	*41.46*	*37.31*
1,500	127.11	8.83E-03	7.06E-03	5.88E-03	5.04E-03	4.41E-03	3.92E-03	3.53E-03
	33,578.65	*139.91*	*111.93*	*93.27*	*79.95*	*69.96*	*62.18*	*55.96*
2,000	169.48	0.01	9.42E-03	7.85E-03	6.73E-03	5.88E-03	5.23E-03	4.71E-03
	44,771.53	*186.55*	*149.24*	*124.37*	*106.60*	*93.27*	*82.91*	*74.62*
2,500	211.85	0.01	0.01	9.81E-03	8.41E-03	7.36E-03	6.54E-03	5.88E-03
	55,964.41	*233.19*	*186.55*	*155.46*	*133.25*	*116.59*	*103.64*	*93.27*
3,000	254.22	0.02	0.01	0.01	0.01	8.83E-03	7.85E-03	7.06E-03
	67,157.30	*279.82*	*223.86*	*186.55*	*159.90*	*139.91*	*124.37*	*111.93*
3,500	296.59	0.02	0.02	0.01	0.01	0.01	9.15E-03	8.24E-03
	78,350.18	*326.46*	*261.17*	*217.64*	*186.55*	*163.23*	*145.09*	*130.58*
4,000	338.96	0.02	0.02	0.02	0.01	0.01	0.01	9.42E-03
	89,543.06	*373.10*	*298.48*	*248.73*	*213.20*	*186.55*	*165.82*	*149.24*
4,500	381.33	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	100,735.95	*419.73*	*335.79*	*279.82*	*239.85*	*209.87*	*186.55*	*167.89*
5,000	423.70	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	111,928.83	*466.37*	*373.10*	*310.91*	*266.50*	*233.19*	*207.28*	*186.55*
5,500	466.07	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	123,121.71	*513.01*	*410.41*	*342.00*	*293.15*	*256.50*	*228.00*	*205.20*
6,000	508.44	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	134,314.59	*559.64*	*447.72*	*373.10*	*319.80*	*279.82*	*248.73*	*223.86*
6,500	550.81	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	145,507.48	*606.28*	*485.02*	*404.19*	*346.45*	*303.14*	*269.46*	*242.51*
7,000	593.18	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	156,700.36	*652.92*	*522.33*	*435.28*	*373.10*	*326.46*	*290.19*	*261.17*
7,500	635.55	0.04	0.04	0.03	0.03	0.02	0.02	0.02
	167,893.24	*699.56*	*559.64*	*466.37*	*399.75*	*349.78*	*310.91*	*279.82*
8,000	677.92	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	179,086.13	*746.19*	*596.95*	*497.46*	*426.40*	*373.10*	*331.64*	*298.48*
8,500	720.29	0.05	0.04	0.03	0.03	0.03	0.02	0.02
	190,279.01	*792.83*	*634.26*	*528.55*	*453.05*	*396.41*	*352.37*	*317.13*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Windsor Airport						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	8.66	6.02E-04	4.81E-04	4.01E-04	3.44E-04	3.01E-04	2.67E-04	2.41E-04
	2,288.77	*9.54*	*7.63*	*6.36*	*5.45*	*4.77*	*4.24*	*3.81*
200	17.33	1.20E-03	9.63E-04	8.02E-04	6.88E-04	6.02E-04	5.35E-04	4.81E-04
	4,577.54	*19.07*	*15.26*	*12.72*	*10.90*	*9.54*	*8.48*	*7.63*
300	25.99	1.81E-03	1.44E-03	1.20E-03	1.03E-03	9.03E-04	8.02E-04	7.22E-04
	6,866.31	*28.61*	*22.89*	*19.07*	*16.35*	*14.30*	*12.72*	*11.44*
400	34.66	2.41E-03	1.93E-03	1.60E-03	1.38E-03	1.20E-03	1.07E-03	9.63E-04
	9,155.08	*38.15*	*30.52*	*25.43*	*21.80*	*19.07*	*16.95*	*15.26*
500	43.32	3.01E-03	2.41E-03	2.01E-03	1.72E-03	1.50E-03	1.34E-03	1.20E-03
	11,443.84	*47.68*	*38.15*	*31.79*	*27.25*	*23.84*	*21.19*	*19.07*
600	51.98	3.61E-03	2.89E-03	2.41E-03	2.06E-03	1.81E-03	1.60E-03	1.44E-03
	13,732.61	*57.22*	*45.78*	*38.15*	*32.70*	*28.61*	*25.43*	*22.89*
700	60.65	4.21E-03	3.37E-03	2.81E-03	2.41E-03	2.11E-03	1.87E-03	1.68E-03
	16,021.38	*66.76*	*53.40*	*44.50*	*38.15*	*33.38*	*29.67*	*26.70*
800	69.31	4.81E-03	3.85E-03	3.21E-03	2.75E-03	2.41E-03	2.14E-03	1.93E-03
	18,310.15	*76.29*	*61.03*	*50.86*	*43.60*	*38.15*	*33.91*	*30.52*
900	77.98	5.42E-03	4.33E-03	3.61E-03	3.09E-03	2.71E-03	2.41E-03	2.17E-03
	20,598.92	*85.83*	*68.66*	*57.22*	*49.05*	*42.91*	*38.15*	*34.33*
1,000	86.64	6.02E-03	4.81E-03	4.01E-03	3.44E-03	3.01E-03	2.67E-03	2.41E-03
	22,887.69	*95.37*	*76.29*	*63.58*	*54.49*	*47.68*	*42.38*	*38.15*
1,500	129.96	9.03E-03	7.22E-03	6.02E-03	5.16E-03	4.51E-03	4.01E-03	3.61E-03
	34,331.53	*143.05*	*114.44*	*95.37*	*81.74*	*71.52*	*63.58*	*57.22*
2,000	173.28	0.01	9.63E-03	8.02E-03	6.88E-03	6.02E-03	5.35E-03	4.81E-03
	45,775.38	*190.73*	*152.58*	*127.15*	*108.99*	*95.37*	*84.77*	*76.29*
2,500	216.60	0.02	0.01	0.01	8.60E-03	7.52E-03	6.69E-03	6.02E-03
	57,219.22	*238.41*	*190.73*	*158.94*	*136.24*	*119.21*	*105.96*	*95.37*
3,000	259.92	0.02	0.01	0.01	0.01	9.03E-03	8.02E-03	7.22E-03
	68,663.07	*286.10*	*228.88*	*190.73*	*163.48*	*143.05*	*127.15*	*114.44*
3,500	303.24	0.02	0.02	0.01	0.01	0.01	9.36E-03	8.42E-03
	80,106.91	*333.78*	*267.02*	*222.52*	*190.73*	*166.89*	*148.35*	*133.51*
4,000	346.56	0.02	0.02	0.02	0.01	0.01	0.01	9.63E-03
	91,550.76	*381.46*	*305.17*	*254.31*	*217.98*	*190.73*	*169.54*	*152.58*
4,500	389.88	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	102,994.60	*429.14*	*343.32*	*286.10*	*245.23*	*214.57*	*190.73*	*171.66*
5,000	433.20	0.03	0.02	0.02	0.02	0.02	0.01	0.01
	114,438.44	*476.83*	*381.46*	*317.88*	*272.47*	*238.41*	*211.92*	*190.73*
5,500	476.52	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	125,882.29	*524.51*	*419.61*	*349.67*	*299.72*	*262.25*	*233.12*	*209.80*
6,000	519.84	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	137,326.13	*572.19*	*457.75*	*381.46*	*326.97*	*286.10*	*254.31*	*228.88*
6,500	563.16	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	148,769.98	*619.87*	*495.90*	*413.25*	*354.21*	*309.94*	*275.50*	*247.95*
7,000	606.48	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	160,213.82	*667.56*	*534.05*	*445.04*	*381.46*	*333.78*	*296.69*	*267.02*
7,500	649.80	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	171,657.67	*715.24*	*572.19*	*476.83*	*408.71*	*357.62*	*317.88*	*286.10*
8,000	693.12	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	183,101.51	*762.92*	*610.34*	*508.62*	*435.96*	*381.46*	*339.08*	*305.17*
8,500	736.44	0.05	0.04	0.03	0.03	0.03	0.02	0.02
	194,545.35	*810.61*	*648.48*	*540.40*	*463.20*	*405.30*	*360.27*	*324.24*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Chatham WPCP						
		Discharge Rate for following Retention Periods						
		4 hr	**5 hr**	**6 hr**	**7 hr**	**8 hr**	**9 hr**	**10 hr**
	(m^3)	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**
	(gal)	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***
100	8.46	5.87E-04	4.70E-04	3.91E-04	3.36E-04	2.94E-04	2.61E-04	2.35E-04
	2,233.56	*9.31*	*7.45*	*6.20*	*5.32*	*4.65*	*4.14*	*3.72*
200	16.91	1.17E-03	9.39E-04	7.83E-04	6.71E-04	5.87E-04	5.22E-04	4.70E-04
	4,467.11	*18.61*	*14.89*	*12.41*	*10.64*	*9.31*	*8.27*	*7.45*
300	25.37	1.76E-03	1.41E-03	1.17E-03	1.01E-03	8.81E-04	7.83E-04	7.05E-04
	6,700.67	*27.92*	*22.34*	*18.61*	*15.95*	*13.96*	*12.41*	*11.17*
400	33.82	2.35E-03	1.88E-03	1.57E-03	1.34E-03	1.17E-03	1.04E-03	9.39E-04
	8,934.23	*37.23*	*29.78*	*24.82*	*21.27*	*18.61*	*16.54*	*14.89*
500	42.28	2.94E-03	2.35E-03	1.96E-03	1.68E-03	1.47E-03	1.30E-03	1.17E-03
	11,167.79	*46.53*	*37.23*	*31.02*	*26.59*	*23.27*	*20.68*	*18.61*
600	50.73	3.52E-03	2.82E-03	2.35E-03	2.01E-03	1.76E-03	1.57E-03	1.41E-03
	13,401.34	*55.84*	*44.67*	*37.23*	*31.91*	*27.92*	*24.82*	*22.34*
700	59.19	4.11E-03	3.29E-03	2.74E-03	2.35E-03	2.06E-03	1.83E-03	1.64E-03
	15,634.90	*65.15*	*52.12*	*43.43*	*37.23*	*32.57*	*28.95*	*26.06*
800	67.64	4.70E-03	3.76E-03	3.13E-03	2.68E-03	2.35E-03	2.09E-03	1.88E-03
	17,868.46	*74.45*	*59.56*	*49.63*	*42.54*	*37.23*	*33.09*	*29.78*
900	76.10	5.28E-03	4.23E-03	3.52E-03	3.02E-03	2.64E-03	2.35E-03	2.11E-03
	20,102.02	*83.76*	*67.01*	*55.84*	*47.86*	*41.88*	*37.23*	*33.50*
1,000	84.55	5.87E-03	4.70E-03	3.91E-03	3.36E-03	2.94E-03	2.61E-03	2.35E-03
	22,335.57	*93.06*	*74.45*	*62.04*	*53.18*	*46.53*	*41.36*	*37.23*
1,500	126.83	8.81E-03	7.05E-03	5.87E-03	5.03E-03	4.40E-03	3.91E-03	3.52E-03
	33,503.36	*139.60*	*111.68*	*93.06*	*79.77*	*69.80*	*62.04*	*55.84*
2,000	169.10	0.01	9.39E-03	7.83E-03	6.71E-03	5.87E-03	5.22E-03	4.70E-03
	44,671.15	*186.13*	*148.90*	*124.09*	*106.36*	*93.06*	*82.72*	*74.45*
2,500	211.38	0.01	0.01	9.79E-03	8.39E-03	7.34E-03	6.52E-03	5.87E-03
	55,838.93	*232.66*	*186.13*	*155.11*	*132.95*	*116.33*	*103.41*	*93.06*
3,000	253.65	0.02	0.01	0.01	0.01	8.81E-03	7.83E-03	7.05E-03
	67,006.72	*279.19*	*223.36*	*186.13*	*159.54*	*139.60*	*124.09*	*111.68*
3,500	295.93	0.02	0.02	0.01	0.01	0.01	9.13E-03	8.22E-03
	78,174.51	*325.73*	*260.58*	*217.15*	*186.13*	*162.86*	*144.77*	*130.29*
4,000	338.20	0.02	0.02	0.02	0.01	0.01	0.01	9.39E-03
	89,342.29	*372.26*	*297.81*	*248.17*	*212.72*	*186.13*	*165.45*	*148.90*
4,500	380.48	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	100,510.08	*418.79*	*335.03*	*279.19*	*239.31*	*209.40*	*186.13*	*167.52*
5,000	422.75	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	111,677.87	*465.32*	*372.26*	*310.22*	*265.90*	*232.66*	*206.81*	*186.13*
5,500	465.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	122,845.65	*511.86*	*409.49*	*341.24*	*292.49*	*255.93*	*227.49*	*204.74*
6,000	507.30	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	134,013.44	*558.39*	*446.71*	*372.26*	*319.08*	*279.19*	*248.17*	*223.36*
6,500	549.58	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	145,181.23	*604.92*	*483.94*	*403.28*	*345.67*	*302.46*	*268.85*	*241.97*
7,000	591.85	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	156,349.01	*651.45*	*521.16*	*434.30*	*372.26*	*325.73*	*289.54*	*260.58*
7,500	634.13	0.04	0.04	0.03	0.03	0.02	0.02	0.02
	167,516.80	*697.99*	*558.39*	*465.32*	*398.85*	*348.99*	*310.22*	*279.19*
8,000	676.40	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	178,684.59	*744.52*	*595.62*	*496.35*	*425.44*	*372.26*	*330.90*	*297.81*
8,500	718.68	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	189,852.37	*791.05*	*632.84*	*527.37*	*452.03*	*395.53*	*351.58*	*316.42*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Owen Sound						
		Discharge Rate for following Retention Periods						
		4 hr	**5 hr**	**6 hr**	**7 hr**	**8 hr**	**9 hr**	**10 hr**
	(m^3)	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**
	(gal)	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***
100	7.44	5.17E-04	4.13E-04	3.44E-04	2.95E-04	2.58E-04	2.30E-04	2.07E-04
	1,965.03	*8.19*	*6.55*	*5.46*	*4.68*	*4.09*	*3.64*	*3.28*
200	14.88	1.03E-03	8.27E-04	6.89E-04	5.90E-04	5.17E-04	4.59E-04	4.13E-04
	3,930.06	*16.38*	*13.10*	*10.92*	*9.36*	*8.19*	*7.28*	*6.55*
300	22.32	1.55E-03	1.24E-03	1.03E-03	8.86E-03	7.75E-04	6.89E-04	6.20E-04
	5,895.09	*24.56*	*19.65*	*16.38*	*14.04*	*12.28*	*10.92*	*9.83*
400	29.75	2.07E-03	1.65E-03	1.38E-03	1.18E-03	1.03E-03	9.18E-04	8.27E-04
	7,860.11	*32.75*	*26.20*	*21.83*	*18.71*	*16.38*	*14.56*	*13.10*
500	37.19	2.58E-03	2.07E-03	1.72E-03	1.48E-03	1.29E-03	1.15E-03	1.03E-03
	9,825.14	*40.94*	*32.75*	*27.29*	*23.39*	*20.47*	*18.19*	*16.38*
600	44.63	3.10E-03	2.48E-03	2.07E-03	1.77E-03	1.55E-03	1.38E-03	1.24E-03
	11,790.17	*49.13*	*39.30*	*32.75*	*28.07*	*24.56*	*21.83*	*19.65*
700	52.07	3.62E-03	2.89E-03	2.41E-03	2.07E-03	1.81E-03	1.61E-03	1.45E-03
	13,755.20	*57.31*	*45.85*	*38.21*	*32.75*	*28.66*	*25.47*	*22.93*
800	59.51	4.13E-03	3.31E-03	2.76E-03	2.36E-03	2.07E-03	1.84E-03	1.65E-03
	15,720.23	*65.50*	*52.40*	*43.67*	*37.43*	*32.75*	*29.11*	*26.20*
900	66.95	4.65E-03	3.72E-03	3.10E-03	2.66E-03	2.32E-03	2.07E-03	1.86E-03
	17,685.26	*73.69*	*58.95*	*49.13*	*42.11*	*36.84*	*32.75*	*29.48*
1,000	74.39	5.17E-03	4.13E-03	3.44E-03	2.95E-03	2.58E-03	2.30E-03	2.07E-03
	19,650.29	*81.88*	*65.50*	*54.58*	*46.79*	*40.94*	*36.39*	*32.75*
1,500	111.58	7.75E-03	6.20E-03	5.17E-03	4.43E-03	3.87E-03	3.44E-03	3.10E-03
	29,475.43	*122.81*	*98.25*	*81.88*	*70.18*	*61.41*	*54.58*	*49.13*
2,000	148.77	0.01	8.27E-03	6.89E-03	5.90E-03	5.17E-03	4.59E-03	4.13E-03
	39,300.57	*163.75*	*131.00*	*109.17*	*93.57*	*81.88*	*72.78*	*65.50*
2,500	185.96	0.01	0.01	8.61E-03	7.38E-03	6.46E-03	5.74E-03	5.17E-03
	49,125.71	*204.69*	*163.75*	*136.46*	*116.97*	*102.35*	*90.97*	*81.88*
3,000	223.16	0.02	0.01	0.01	8.86E-03	7.75E-03	6.89E-03	6.20E-03
	58,950.86	*245.63*	*196.50*	*163.75*	*140.36*	*122.81*	*109.17*	*98.25*
3,500	260.35	0.02	0.01	0.01	0.01	9.04E-03	8.04E-03	7.23E-03
	68,776.00	*286.57*	*229.25*	*191.04*	*163.75*	*143.28*	*127.36*	*114.63*
4,000	297.54	0.02	0.02	0.01	0.01	0.01	9.18E-03	8.27E-03
	78,601.14	*327.50*	*262.00*	*218.34*	*187.15*	*163.75*	*145.56*	*131.00*
4,500	334.73	0.02	0.02	0.02	0.01	0.01	0.01	9.30E-03
	88,426.28	*368.44*	*294.75*	*245.63*	*210.54*	*184.22*	*163.75*	*147.38*
5,000	371.93	0.03	0.02	0.02	0.01	0.01	0.01	0.01
	98,251.43	*409.38*	*327.50*	*272.92*	*233.93*	*204.69*	*181.95*	*163.75*
5,500	409.12	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	108,076.57	*450.32*	*360.26*	*300.21*	*257.33*	*225.16*	*200.14*	*180.13*
6,000	446.31	0.03	0.02	0.02	0.02	0.02	0.01	0.01
	117,901.71	*491.26*	*393.01*	*327.50*	*280.72*	*245.63*	*218.34*	*196.50*
6,500	483.50	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	127,726.86	*532.20*	*425.76*	*354.80*	*304.11*	*266.10*	*236.53*	*212.88*
7,000	520.70	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	137,552.00	*573.13*	*458.51*	*382.09*	*327.50*	*286.57*	*254.73*	*229.25*
7,500	557.89	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	147,377.14	*614.07*	*491.26*	*409.38*	*350.90*	*307.04*	*272.92*	*245.63*
8,000	595.08	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	157,202.28	*655.01*	*524.01*	*436.67*	*374.29*	*327.50*	*291.12*	*262.00*
8,500	632.27	0.04	0.04	0.03	0.03	0.02	0.02	0.02
	167,027.43	*695.95*	*556.76*	*463.97*	*397.68*	*347.97*	*309.31*	*278.38*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	**Storage/ Settling Volume***	**Stratford MOE**						
		Discharge Rate for following Retention Periods						
		4 hr	**5 hr**	**6 hr**	**7 hr**	**8 hr**	**9 hr**	**10 hr**
	(m^3)	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**
	(gal)	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***
100	10.91	7.57E-04	6.06E-04	5.05E-04	4.33E-04	3.79E-04	3.37E-04	3.03E-04
	2,881.04	*12.00*	*9.60*	*8.00*	*6.86*	*6.00*	*5.34*	*4.80*
200	21.81	1.51E-03	1.21E-03	1.01E-03	8.66E-04	7.57E-04	6.73E-04	6.06E-04
	5,762.08	*24.01*	*19.21*	*16.01*	*13.72*	*12.00*	*10.67*	*9.60*
300	32.72	2.27E-03	1.82E-03	1.51E-03	1.30E-03	1.14E-03	1.01E-03	9.09E-04
	8,643.11	*36.01*	*28.81*	*24.01*	*20.58*	*18.01*	*16.01*	*14.41*
400	43.62	3.03E-03	2.42E-03	2.02E-03	1.73E-03	1.51E-03	1.35E-03	1.21E-03
	11,524.15	*48.02*	*38.41*	*32.01*	*27.44*	*24.01*	*21.34*	*19.21*
500	54.53	3.79E-03	3.03E-03	2.52E-03	2.16E-03	1.89E-03	1.68E-03	1.51E-03
	14,405.19	*60.02*	*48.02*	*40.01*	*34.30*	*30.01*	*26.68*	*24.01*
600	65.44	4.54E-03	3.64E-03	3.03E-03	2.60E-03	2.27E-03	2.02E-03	1.82E-03
	17,286.23	*72.03*	*57.62*	*48.02*	*41.16*	*36.01*	*32.01*	*28.81*
700	76.34	5.30E-03	4.24E-03	3.53E-03	3.03E-03	2.65E-03	2.36E-03	2.12E-03
	20,167.27	*84.03*	*67.22*	*56.02*	*48.02*	*42.02*	*37.35*	*33.61*
800	87.25	6.06E-03	4.85E-03	4.04E-03	3.46E-03	3.03E-03	2.69E-03	2.42E-03
	23,048.30	*96.03*	*76.83*	*64.02*	*54.88*	*48.02*	*42.68*	*38.41*
900	98.15	6.82E-03	5.45E-03	4.54E-03	3.90E-03	3.41E-03	3.03E-03	2.73E-03
	25,929.34	*108.04*	*86.43*	*72.03*	*61.74*	*54.02*	*48.02*	*43.22*
1,000	109.06	7.57E-03	6.06E-03	5.05E-03	4.33E-03	3.79E-03	3.37E-03	3.03E-03
	28,810.38	*120.04*	*96.03*	*80.03*	*68.60*	*60.02*	*53.35*	*48.02*
1,500	163.59	0.01	9.09E-03	7.57E-03	6.49E-03	5.68E-03	5.05E-03	4.54E-03
	43,215.57	*180.06*	*144.05*	*120.04*	*102.89*	*90.03*	*80.03*	*72.03*
2,000	218.12	0.02	0.01	0.01	8.66E-03	7.57E-03	6.73E-03	6.06E-03
	57,620.76	*240.09*	*192.07*	*160.06*	*137.19*	*120.04*	*106.71*	*96.03*
2,500	272.65	0.02	0.02	0.01	0.01	9.47E-03	8.42E-03	7.57E-03
	72,025.95	*300.11*	*240.09*	*200.07*	*171.49*	*150.05*	*133.38*	*120.04*
3,000	327.18	0.02	0.02	0.02	0.01	0.01	0.01	9.09E-03
	86,431.14	*360.13*	*288.10*	*240.09*	*205.79*	*180.06*	*160.06*	*144.05*
3,500	381.71	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	100,836.33	*420.15*	*336.12*	*280.10*	*240.09*	*210.08*	*186.73*	*168.06*
4,000	436.24	0.03	0.02	0.02	0.02	0.02	0.01	0.01
	115,241.52	*480.17*	*384.14*	*320.12*	*274.38*	*240.09*	*213.41*	*192.07*
4,500	490.77	0.03	0.03	0.02	0.02	0.02	0.02	0.01
	129,646.71	*540.19*	*432.16*	*360.13*	*308.68*	*270.10*	*240.09*	*216.08*
5,000	545.30	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	144,051.90	*600.22*	*480.17*	*400.14*	*342.98*	*300.11*	*266.76*	*240.09*
5,500	599.83	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	158,457.09	*660.24*	*528.19*	*440.16*	*377.28*	*330.12*	*293.44*	*264.10*
6,000	654.36	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	172,862.28	*720.26*	*576.21*	*480.17*	*411.58*	*360.13*	*320.12*	*288.10*
6,500	708.89	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	187,267.47	*780.28*	*624.22*	*520.19*	*445.87*	*390.14*	*346.79*	*312.11*
7,000	763.42	0.05	0.04	0.04	0.03	0.03	0.02	0.02
	201,672.66	*840.30*	*672.24*	*560.20*	*480.17*	*420.15*	*373.47*	*336.12*
7,500	817.95	0.06	0.05	0.04	0.03	0.03	0.03	0.02
	216,077.85	*900.32*	*720.26*	*600.22*	*514.47*	*450.16*	*400.14*	*360.13*
8,000	872.48	0.06	0.05	0.04	0.03	0.03	0.03	0.02
	230,483.04	*960.35*	*768.28*	*640.23*	*548.77*	*480.17*	*426.82*	*384.14*
8,500	927.01	0.06	0.05	0.04	0.04	0.03	0.03	0.03
	244,888.23	*1,020.37*	*816.29*	*680.25*	*583.07*	*510.18*	*453.50*	*408.15*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Brantford MOE						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	7.63	5.30E-04	4.24E-04	3.53E-04	3.03E-04	2.65E-04	2.35E-04	2.12E-04
	2,015.22	*8.40*	*6.72*	*5.60*	*4.80*	*4.20*	*3.73*	*3.36*
200	15.26	1.06E-03	8.48E-04	7.06E-04	6.05E-04	5.30E-04	4.71E-04	4.24E-04
	4,030.44	*16.79*	*13.43*	*11.20*	*9.60*	*8.40*	*7.46*	*6.72*
300	22.89	1.59E-03	1.27E-03	1.06E-03	9.08E-04	7.95E-04	7.06E-04	6.36E-04
	6,045.66	*25.19*	*20.15*	*16.79*	*14.39*	*12.60*	*11.20*	*10.08*
400	30.51	2.12E-03	1.70E-03	1.41E-03	1.21E-03	1.06E-03	9.42E-04	8.48E-04
	8,060.88	*33.59*	*26.87*	*22.39*	*19.19*	*16.79*	*14.93*	*13.43*
500	38.14	2.65E-03	2.12E-03	1.77E-03	1.51E-03	1.32E-03	1.18E-03	1.06E-03
	10,076.10	*41.98*	*33.59*	*27.99*	*23.99*	*20.99*	*18.66*	*16.79*
600	45.77	3.18E-03	2.54E-03	2.12E-03	1.82E-03	1.59E-03	1.41E-03	1.27E-03
	12,091.33	*50.38*	*40.30*	*33.59*	*28.79*	*25.19*	*22.39*	*20.15*
700	53.40	3.71E-03	2.97E-03	2.47E-03	2.12E-03	1.85E-03	1.65E-03	1.48E-03
	14,106.55	*58.78*	*47.02*	*39.18*	*33.59*	*29.39*	*26.12*	*23.51*
800	61.03	4.24E-03	3.39E-03	2.83E-03	2.42E-03	2.12E-03	1.88E-03	1.70E-03
	16,121.77	*67.17*	*53.74*	*44.78*	*38.39*	*33.59*	*29.86*	*26.87*
900	68.66	4.77E-03	3.81E-03	3.18E-03	2.72E-03	2.38E-03	2.12E-03	1.91E-03
	18,136.99	*75.57*	*60.46*	*50.38*	*43.18*	*37.79*	*33.59*	*30.23*
1,000	76.29	5.30E-03	4.24E-03	3.53E-03	3.03E-03	2.65E-03	2.35E-03	2.12E-03
	20,152.21	*83.97*	*67.17*	*55.98*	*47.98*	*41.98*	*37.32*	*33.59*
1,500	114.43	7.95E-03	6.36E-03	5.30E-03	4.54E-03	3.97E-03	3.53E-03	3.18E-03
	30,228.31	*125.95*	*100.76*	*83.97*	*71.97*	*62.98*	*55.98*	*50.38*
2,000	152.57	0.01	8.48E-03	7.06E-03	6.05E-03	5.30E-03	4.71E-03	4.24E-03
	40,304.42	*167.94*	*134.35*	*111.96*	*95.96*	*83.97*	*74.64*	*67.17*
2,500	190.71	0.01	0.01	8.83E-03	7.57E-03	6.62E-03	5.89E-03	5.30E-03
	50,380.52	*209.92*	*167.94*	*139.95*	*119.95*	*104.96*	*93.30*	*83.97*
3,000	228.86	0.02	0.01	0.01	9.08E-03	7.95E-03	7.06E-03	6.36E-03
	60,456.63	*251.90*	*201.52*	*167.94*	*143.94*	*125.95*	*111.96*	*100.76*
3,500	267.00	0.02	0.01	0.01	0.01	9.27E-03	8.24E-03	7.42E-03
	70,532.73	*293.89*	*235.11*	*195.92*	*167.94*	*146.94*	*130.62*	*117.55*
4,000	305.14	0.02	0.02	0.01	0.01	0.01	9.42E-03	8.48E-03
	80,608.83	*335.87*	*268.70*	*223.91*	*191.93*	*167.94*	*149.28*	*134.35*
4,500	343.28	0.02	0.02	0.02	0.01	0.01	0.01	9.54E-03
	90,684.94	*377.85*	*302.28*	*251.90*	*215.92*	*188.93*	*167.94*	*151.14*
5,000	381.43	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	100,761.04	*419.84*	*335.87*	*279.89*	*239.91*	*209.92*	*186.59*	*167.94*
5,500	419.57	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	110,837.15	*461.82*	*369.46*	*307.88*	*263.90*	*230.91*	*205.25*	*184.73*
6,000	457.71	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	120,913.25	*503.81*	*403.04*	*335.87*	*287.89*	*251.90*	*223.91*	*201.52*
6,500	495.85	0.03	0.03	0.02	0.02	0.02	0.02	0.01
	130,989.35	*545.79*	*436.63*	*363.86*	*311.88*	*272.89*	*242.57*	*218.32*
7,000	534.00	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	141,065.46	*587.77*	*470.22*	*391.85*	*335.87*	*293.89*	*261.23*	*235.11*
7,500	572.14	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	151,141.56	*629.76*	*503.81*	*419.84*	*359.86*	*314.88*	*279.89*	*251.90*
8,000	610.28	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	161,217.67	*671.74*	*537.39*	*447.83*	*383.85*	*335.87*	*298.55*	*268.70*
8,500	648.42	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	171,293.77	*713.72*	*570.98*	*475.82*	*407.84*	*356.86*	*317.21*	*285.49*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Guelph Arboretum						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	8.20	5.69E-04	4.55E-04	3.80E-04	3.25E-04	2.85E-04	2.53E-04	2.28E-04
	2,165.80	*9.02*	*7.22*	*6.02*	*5.16*	*4.51*	*4.01*	*3.61*
200	16.40	1.14E-03	9.11E-04	7.59E-04	6.51E-04	5.69E-04	5.06E-04	4.55E-04
	4,331.60	*18.05*	*14.44*	*12.03*	*10.31*	*9.02*	*8.02*	*7.22*
300	24.60	1.71E-03	1.37E-03	1.14E-03	9.76E-04	8.54E-04	7.59E-04	6.83E-04
	6,497.39	*27.07*	*21.66*	*18.05*	*15.47*	*13.54*	*12.03*	*10.83*
400	32.79	2.28E-03	1.82E-03	1.52E-03	1.30E-03	1.14E-03	1.01E-03	9.11E-04
	8,663.19	*36.10*	*28.88*	*24.06*	*20.63*	*18.05*	*16.04*	*14.44*
500	40.99	2.85E-03	2.28E-03	1.90E-03	1.63E-03	1.42E-03	1.27E-03	1.14E-03
	10,828.99	*45.12*	*36.10*	*30.08*	*25.78*	*22.56*	*20.05*	*18.05*
600	49.19	3.42E-03	2.73E-03	2.28E-03	1.95E-03	1.71E-03	1.52E-03	1.37E-03
	12,994.79	*54.14*	*43.32*	*36.10*	*30.94*	*27.07*	*24.06*	*21.66*
700	57.39	3.99E-03	3.19E-03	2.66E-03	2.28E-03	1.99E-03	1.77E-03	1.59E-03
	15,160.58	*63.17*	*50.54*	*42.11*	*36.10*	*31.58*	*28.08*	*25.27*
800	65.59	4.55E-03	3.64E-03	3.04E-03	2.60E-03	2.28E-03	2.02E-03	1.82E-03
	17,326.38	*72.19*	*57.75*	*48.13*	*41.25*	*36.10*	*32.09*	*28.88*
900	73.79	5.12E-03	4.10E-03	3.42E-03	2.93E-03	2.56E-03	2.28E-03	2.05E-03
	19,492.18	*81.22*	*64.97*	*54.14*	*46.41*	*40.61*	*36.10*	*32.49*
1,000	81.99	5.69E-03	4.55E-03	3.80E-03	3.25E-03	2.85E-03	2.53E-03	2.28E-03
	21,657.98	*90.24*	*72.19*	*60.16*	*51.57*	*45.12*	*40.11*	*36.10*
1,500	122.98	8.54E-03	6.83E-03	5.69E-03	4.88E-03	4.27E-03	3.80E-03	3.42E-03
	32,486.97	*135.36*	*108.29*	*90.24*	*77.35*	*67.68*	*60.16*	*54.14*
2,000	163.97	0.01	9.11E-03	7.59E-03	6.51E-03	5.69E-03	5.06E-03	4.55E-03
	43,315.95	*180.48*	*144.39*	*120.32*	*103.13*	*90.24*	*80.21*	*72.19*
2,500	204.96	0.01	0.01	9.49E-03	8.13E-03	7.12E-03	6.33E-03	5.69E-03
	54,144.94	*225.60*	*180.48*	*150.40*	*128.92*	*112.80*	*100.27*	*90.24*
3,000	245.96	0.02	0.01	0.01	9.76E-03	8.54E-03	7.59E-03	6.83E-03
	64,973.93	*270.72*	*216.58*	*180.48*	*154.70*	*135.36*	*120.32*	*108.29*
3,500	286.95	0.02	0.02	0.01	0.01	9.96E-03	8.86E-03	7.97E-03
	75,802.92	*315.85*	*252.68*	*210.56*	*180.48*	*157.92*	*140.38*	*126.34*
4,000	327.94	0.02	0.02	0.02	0.01	0.01	0.01	9.11E-03
	86,631.91	*360.97*	*288.77*	*240.64*	*206.27*	*180.48*	*160.43*	*144.39*
4,500	368.93	0.03	0.02	0.02	0.01	0.01	0.01	0.01
	97,460.90	*406.09*	*324.87*	*270.72*	*232.05*	*203.04*	*180.48*	*162.43*
5,000	409.93	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	108,289.89	*451.21*	*360.97*	*300.81*	*257.83*	*225.60*	*200.54*	*180.48*
5,500	450.92	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	119,118.88	*496.33*	*397.06*	*330.89*	*283.62*	*248.16*	*220.59*	*198.53*
6,000	491.91	0.03	0.03	0.02	0.02	0.02	0.02	0.01
	129,947.86	*541.45*	*433.16*	*360.97*	*309.40*	*270.72*	*240.64*	*216.58*
6,500	532.90	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	140,776.85	*586.57*	*469.26*	*391.05*	*335.18*	*293.29*	*260.70*	*234.63*
7,000	573.90	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	151,605.84	*631.69*	*505.35*	*421.13*	*360.97*	*315.85*	*280.75*	*252.68*
7,500	614.89	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	162,434.83	*676.81*	*541.45*	*451.21*	*386.75*	*338.41*	*300.81*	*270.72*
8,000	655.88	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	173,263.82	*721.93*	*577.55*	*481.29*	*412.53*	*360.97*	*320.86*	*288.77*
8,500	696.87	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	184,092.81	*767.05*	*613.64*	*511.37*	*438.32*	*383.53*	*340.91*	*306.82*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Hamilton Airport						
		Discharge Rate for following Retention Periods						
		4 hr	**5 hr**	**6 hr**	**7 hr**	**8 hr**	**9 hr**	**10 hr**
	(m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	9.61	6.68E-04	5.34E-04	4.45E-04	3.82E-04	3.34E-04	2.97E-04	2.67E-04
	2,539.73	*10.58*	*8.47*	*7.05*	*6.05*	*5.29*	*4.70*	*4.23*
200	19.23	1.34E-03	1.07E-03	8.90E-04	7.63E-04	6.68E-04	5.93E-04	5.34E-04
	5,079.46	*21.16*	*16.93*	*14.11*	*12.09*	*10.58*	*9.41*	*8.47*
300	28.84	2.00E-03	1.60E-03	1.34E-03	1.14E-03	1.00E-03	8.90E-04	8.01E-04
	7,619.19	*31.75*	*25.40*	*21.16*	*18.14*	*15.87*	*14.11*	*12.70*
400	38.46	2.67E-03	2.14E-03	1.78E-03	1.53E-03	1.34E-03	1.19E-03	1.07E-03
	10,158.92	*42.33*	*33.86*	*28.22*	*24.19*	*21.16*	*18.81*	*16.93*
500	48.07	3.34E-03	2.67E-03	2.23E-03	1.91E-03	1.67E-03	1.48E-03	1.34E-03
	12,698.65	*52.91*	*42.33*	*35.27*	*30.23*	*26.46*	*23.52*	*21.16*
600	57.68	4.01E-03	3.20E-03	2.67E-03	2.29E-03	2.00E-03	1.78E-03	1.60E-03
	15,238.38	*63.49*	*50.79*	*42.33*	*36.28*	*31.75*	*28.22*	*25.40*
700	67.30	4.67E-03	3.74E-03	3.12E-03	2.67E-03	2.34E-03	2.08E-03	1.87E-03
	17,778.11	*74.08*	*59.26*	*49.38*	*42.33*	*37.04*	*32.92*	*29.63*
800	76.91	5.34E-03	4.27E-03	3.56E-03	3.05E-03	2.67E-03	2.37E-03	2.14E-03
	20,317.84	*84.66*	*67.73*	*56.44*	*48.38*	*42.33*	*37.63*	*33.86*
900	86.53	6.01E-03	4.81E-03	4.01E-03	3.43E-03	3.00E-03	2.67E-03	2.40E-03
	22,857.57	*95.24*	*76.19*	*63.49*	*54.42*	*47.62*	*42.33*	*38.10*
1,000	96.14	6.68E-03	5.34E-03	4.45E-03	3.82E-03	3.34E-03	2.97E-03	2.67E-03
	25,397.30	*105.82*	*84.66*	*70.55*	*60.47*	*52.91*	*47.03*	*42.33*
1,500	144.21	0.01	8.01E-03	6.68E-03	5.72E-03	5.01E-03	4.45E-03	4.01E-03
	38,095.96	*158.73*	*126.99*	*105.82*	*90.70*	*79.37*	*70.55*	*63.49*
2,000	192.28	0.01	0.01	8.90E-03	7.63E-03	6.68E-03	5.93E-03	5.34E-03
	50,794.61	*211.64*	*169.32*	*141.10*	*120.94*	*105.82*	*94.06*	*84.66*
2,500	240.35	0.02	0.01	0.01	9.54E-03	8.35E-03	7.42E-03	6.68E-03
	63,493.26	*264.56*	*211.64*	*176.37*	*151.17*	*132.28*	*117.58*	*105.82*
3,000	288.42	0.02	0.02	0.01	0.01	0.01	8.90E-03	8.01E-03
	76,191.91	*317.47*	*253.97*	*211.64*	*181.41*	*158.73*	*141.10*	*126.99*
3,500	336.49	0.02	0.02	0.02	0.01	0.01	0.01	9.35E-03
	88,890.56	*370.38*	*296.30*	*246.92*	*211.64*	*185.19*	*164.61*	*148.15*
4,000	384.56	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	101,589.22	*423.29*	*338.63*	*282.19*	*241.88*	*211.64*	*188.13*	*169.32*
4,500	432.63	0.03	0.02	0.02	0.02	0.02	0.01	0.01
	114,287.87	*476.20*	*380.96*	*317.47*	*272.11*	*238.10*	*211.64*	*190.48*
5,000	480.70	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	126,986.52	*529.11*	*423.29*	*352.74*	*302.35*	*264.56*	*235.16*	*211.64*
5,500	528.77	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	139,685.17	*582.02*	*465.62*	*388.01*	*332.58*	*291.01*	*258.68*	*232.81*
6,000	576.84	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	152,383.82	*634.93*	*507.95*	*423.29*	*362.82*	*317.47*	*282.19*	*253.97*
6,500	624.91	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	165,082.47	*687.84*	*550.27*	*458.56*	*393.05*	*343.92*	*305.71*	*275.14*
7,000	672.98	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	177,781.13	*740.75*	*592.60*	*493.84*	*423.29*	*370.38*	*329.22*	*296.30*
7,500	721.05	0.05	0.04	0.03	0.03	0.03	0.02	0.02
	190,479.78	*793.67*	*634.93*	*529.11*	*453.52*	*396.83*	*352.74*	*317.47*
8,000	769.12	0.05	0.04	0.04	0.03	0.03	0.02	0.02
	203,178.43	*846.58*	*677.26*	*564.38*	*483.76*	*423.29*	*376.26*	*338.63*
8,500	817.19	0.06	0.05	0.04	0.03	0.03	0.03	0.02
	215,877.08	*899.49*	*719.59*	*599.66*	*513.99*	*449.74*	*399.77*	*359.80*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Toronto Pearson Int. Airport						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	9.22	6.40E-04	5.12E-04	4.27E-04	3.66E-04	3.20E-04	2.84E-04	2.56E-04
	2,434.33	*10.14*	*8.11*	*6.76*	*5.80*	*5.07*	*4.51*	*4.06*
200	18.43	1.28E-03	1.02E-03	8.53E-04	7.31E-04	6.40E-04	5.69E-04	5.12E-04
	4,868.65	*20.29*	*16.23*	*13.52*	*11.59*	*10.14*	*9.02*	*8.11*
300	27.65	1.92E-03	1.54E-03	1.28E-03	1.10E-03	9.60E-04	8.53E-04	7.68E-04
	7,302.98	*30.43*	*24.34*	*20.29*	*17.39*	*15.21*	*13.52*	*12.17*
400	36.86	2.56E-03	2.05E-03	1.71E-03	1.46E-03	1.28E-03	1.14E-03	1.02E-03
	9,737.31	*40.57*	*32.46*	*27.05*	*23.18*	*20.29*	*18.03*	*16.23*
500	46.08	3.20E-03	2.56E-03	2.13E-03	1.83E-03	1.60E-03	1.42E-03	1.28E-03
	12,171.63	*50.72*	*40.57*	*33.81*	*28.98*	*25.36*	*22.54*	*20.29*
600	55.29	3.84E-03	3.07E-03	2.56E-03	2.19E-03	1.92E-03	1.71E-03	1.54E-03
	14,605.96	*60.86*	*48.69*	*40.57*	*34.78*	*30.43*	*27.05*	*24.34*
700	64.51	4.48E-03	3.58E-03	2.99E-03	2.56E-03	2.24E-03	1.99E-03	1.79E-03
	17,040.29	*71.00*	*56.80*	*47.33*	*40.57*	*35.50*	*31.56*	*28.40*
800	73.72	5.12E-03	4.10E-03	3.41E-03	2.93E-03	2.56E-03	2.28E-03	2.05E-03
	19,474.61	*81.14*	*64.92*	*54.10*	*46.37*	*40.57*	*36.06*	*32.46*
900	82.94	5.76E-03	4.61E-03	3.84E-03	3.29E-03	2.88E-03	2.56E-03	2.30E-03
	21,908.94	*91.29*	*73.03*	*60.86*	*52.16*	*45.64*	*40.57*	*36.51*
1,000	92.15	6.40E-03	5.12E-03	4.27E-03	3.66E-03	3.20E-03	2.84E-03	2.56E-03
	24,343.27	*101.43*	*81.14*	*67.62*	*57.96*	*50.72*	*45.08*	*40.57*
1,500	138.23	9.60E-03	7.68E-03	6.40E-03	5.49E-03	4.80E-03	4.27E-03	3.84E-03
	36,514.90	*152.15*	*121.72*	*101.43*	*86.94*	*76.07*	*67.62*	*60.86*
2,000	184.30	0.01	0.01	8.53E-03	7.31E-03	6.40E-03	5.69E-03	5.12E-03
	48,686.53	*202.86*	*162.29*	*135.24*	*115.92*	*101.43*	*90.16*	*81.14*
2,500	230.38	0.02	0.01	0.01	9.14E-03	8.00E-03	7.11E-03	6.40E-03
	60,858.16	*253.58*	*202.86*	*169.05*	*144.90*	*126.79*	*112.70*	*101.43*
3,000	276.45	0.02	0.02	0.01	0.01	9.60E-03	8.53E-03	7.68E-03
	73,029.80	*304.29*	*243.43*	*202.86*	*173.88*	*152.15*	*135.24*	*121.72*
3,500	322.53	0.02	0.02	0.01	0.01	0.01	9.95E-03	8.96E-03
	85,201.43	*355.01*	*284.00*	*236.67*	*202.86*	*177.50*	*157.78*	*142.00*
4,000	368.60	0.03	0.02	0.02	0.01	0.01	0.01	0.01
	97,373.06	*405.72*	*324.58*	*270.48*	*231.84*	*202.86*	*180.32*	*162.29*
4,500	414.68	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	109,544.69	*456.44*	*365.15*	*304.29*	*260.82*	*228.22*	*202.86*	*182.57*
5,000	460.75	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	121,716.33	*507.15*	*405.72*	*338.10*	*289.80*	*253.58*	*225.40*	*202.86*
5,500	506.83	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	133,887.96	*557.87*	*446.29*	*371.91*	*318.78*	*278.93*	*247.94*	*223.15*
6,000	552.90	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	146,059.59	*608.58*	*486.87*	*405.72*	*347.76*	*304.29*	*270.48*	*243.43*
6,500	598.98	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	158,231.23	*659.30*	*527.44*	*439.53*	*376.74*	*329.65*	*293.02*	*263.72*
7,000	645.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02
	170,402.86	*710.01*	*568.01*	*473.34*	*405.72*	*355.01*	*315.56*	*284.00*
7,500	691.13	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	182,574.49	*760.73*	*608.58*	*507.15*	*434.70*	*380.36*	*338.10*	*304.29*
8,000	737.20	0.05	0.04	0.03	0.03	0.03	0.02	0.02
	194,746.12	*811.44*	*649.15*	*540.96*	*463.68*	*405.72*	*360.64*	*324.58*
8,500	783.28	0.05	0.04	0.04	0.03	0.03	0.02	0.02
	206,917.76	*862.16*	*689.73*	*574.77*	*492.66*	*431.08*	*383.18*	*344.86*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m²)	Storage/ Settling Volume*	Barrie WPCP						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m³)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	9.04	6.28E-04	5.02E-04	4.19E-04	3.59E-04	3.14E-04	2.79E-04	2.51E-04
	2,389.15	*9.95*	*7.96*	*6.64*	*5.69*	*4.98*	*4.42*	*3.98*
200	18.09	1.26E-03	1.00E-03	8.37E-04	7.18E-04	6.28E-04	5.58E-04	5.02E-04
	4,778.31	*19.91*	*15.93*	*13.27*	*11.38*	*9.95*	*8.85*	*7.96*
300	27.13	1.88E-03	1.51E-03	1.26E-03	1.08E-03	9.42E-04	8.37E-04	7.54E-04
	7,167.46	*29.86*	*23.89*	*19.91*	*17.07*	*14.93*	*13.27*	*11.95*
400	36.18	2.51E-03	2.01E-03	1.67E-03	1.44E-03	1.26E-03	1.12E-03	1.00E-03
	9,556.61	*39.82*	*31.86*	*26.55*	*22.75*	*19.91*	*17.70*	*15.93*
500	45.22	3.14E-03	2.51E-03	2.09E-03	1.79E-03	1.57E-03	1.40E-03	1.26E-03
	11,945.77	*49.77*	*39.82*	*33.18*	*28.44*	*24.89*	*22.12*	*19.91*
600	54.26	3.77E-03	3.01E-03	2.51E-03	2.15E-03	1.88E-03	1.67E-03	1.51E-03
	14,334.92	*59.73*	*47.78*	*39.82*	*34.13*	*29.86*	*26.55*	*23.89*
700	63.31	4.40E-03	3.52E-03	2.93E-03	2.51E-03	2.20E-03	1.95E-03	1.76E-03
	16,724.07	*69.68*	*55.75*	*46.46*	*39.82*	*34.84*	*30.97*	*27.87*
800	72.35	5.02E-03	4.02E-03	3.35E-03	2.87E-03	2.51E-03	2.23E-03	2.01E-03
	19,113.23	*79.64*	*63.71*	*53.09*	*45.51*	*39.82*	*35.39*	*31.86*
900	81.40	5.65E-03	4.52E-03	3.77E-03	3.23E-03	2.83E-03	2.51E-03	2.26E-03
	21,502.38	*89.59*	*71.67*	*59.73*	*51.20*	*44.80*	*39.82*	*35.84*
1,000	90.44	6.28E-03	5.02E-03	4.19E-03	3.59E-03	3.14E-03	2.79E-03	2.51E-03
	23,891.53	*99.55*	*79.64*	*66.37*	*56.88*	*49.77*	*44.24*	*39.82*
1,500	135.66	9.42E-03	7.54E-03	6.28E-03	5.38E-03	4.71E-03	4.19E-03	3.77E-03
	35,837.30	*149.32*	*119.46*	*99.55*	*85.33*	*74.66*	*66.37*	*59.73*
2,000	180.88	0.01	0.01	8.37E-03	7.18E-03	6.28E-03	5.58E-03	5.02E-03
	47,783.07	*199.10*	*159.28*	*132.73*	*113.77*	*99.55*	*88.49*	*79.64*
2,500	226.10	0.02	0.01	0.01	8.97E-03	7.85E-03	6.98E-03	6.28E-03
	59,728.84	*248.87*	*199.10*	*165.91*	*142.21*	*124.44*	*110.61*	*99.55*
3,000	271.32	0.02	0.02	0.01	0.01	9.42E-03	8.37E-03	7.54E-03
	71,674.60	*298.64*	*238.92*	*199.10*	*170.65*	*149.32*	*132.73*	*119.46*
3,500	316.54	0.02	0.02	0.01	0.01	0.01	9.77E-03	8.79E-03
	83,620.37	*348.42*	*278.73*	*232.28*	*199.10*	*174.21*	*154.85*	*139.37*
4,000	361.76	0.03	0.02	0.02	0.01	0.01	0.01	0.01
	95,566.14	*398.19*	*318.55*	*265.46*	*227.54*	*199.10*	*176.97*	*159.28*
4,500	406.98	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	107,511.91	*447.97*	*358.37*	*298.64*	*255.98*	*223.98*	*199.10*	*179.19*
5,000	452.20	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	119,457.67	*497.74*	*398.19*	*331.83*	*284.42*	*248.87*	*221.22*	*199.10*
5,500	497.42	0.03	0.03	0.02	0.02	0.02	0.02	0.01
	131,403.44	*547.51*	*438.01*	*365.01*	*312.87*	*273.76*	*243.34*	*219.01*
6,000	542.64	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	143,349.21	*597.29*	*477.83*	*398.19*	*341.31*	*298.64*	*265.46*	*238.92*
6,500	587.86	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	155,294.98	*647.06*	*517.65*	*431.37*	*369.75*	*323.53*	*287.58*	*258.82*
7,000	633.08	0.04	0.04	0.03	0.03	0.02	0.02	0.02
	167,240.74	*696.84*	*557.47*	*464.56*	*398.19*	*348.42*	*309.71*	*278.73*
7,500	678.30	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	179,186.51	*746.61*	*597.29*	*497.74*	*426.63*	*373.31*	*331.83*	*298.64*
8,000	723.52	0.05	0.04	0.03	0.03	0.03	0.02	0.02
	191,132.28	*796.38*	*637.11*	*530.92*	*455.08*	*398.19*	*353.95*	*318.55*
8,500	768.74	0.05	0.04	0.04	0.03	0.03	0.02	0.02
	203,078.05	*846.16*	*676.93*	*564.11*	*483.52*	*423.08*	*376.07*	*338.46*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Oshawa WPCP						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
	(gal)	(gal/min)	(gal/min)	(gal/min)	(gal/min)	(gal/min)	(gal/min)	(gal/min)
100	6.91	4.80E-04	3.84E-04	3.20E-04	2.74E-04	2.40E-04	2.13E-04	1.92E-04
	1,824.49	7.60	6.08	5.07	4.34	3.80	3.38	3.04
200	13.81	9.59E-04	7.67E-04	6.39E-04	5.48E-04	4.80E-04	4.26E-04	3.84E-04
	3,648.98	15.20	12.16	10.14	8.69	7.60	6.76	6.08
300	20.72	1.44E-03	1.15E-03	9.59E-04	8.22E-04	7.19E-04	6.39E-04	5.76E-04
	5,473.47	22.81	18.24	15.20	13.03	11.40	10.14	9.12
400	27.63	1.92E-03	1.53E-03	1.28E-03	1.10E-03	9.59E-04	8.53E-04	7.67E-04
	7,297.96	30.41	24.33	20.27	17.38	15.20	13.51	12.16
500	34.53	2.40E-03	1.92E-03	1.60E-03	1.37E-03	1.20E-03	1.07E-03	9.59E-04
	9,122.45	38.01	30.41	25.34	21.72	19.01	16.89	15.20
600	41.44	2.88E-03	2.30E-03	1.92E-03	1.64E-03	1.44E-03	1.28E-03	1.15E-03
	10,946.94	45.61	36.49	30.41	26.06	22.81	20.27	18.24
700	48.35	3.36E-03	2.69E-03	2.24E-03	1.92E-03	1.68E-03	1.49E-03	1.34E-03
	12,771.43	53.21	42.57	35.48	30.41	26.61	23.65	21.29
800	55.25	3.84E-03	3.07E-03	2.56E-03	2.19E-03	1.92E-03	1.71E-03	1.53E-03
	14,595.92	60.82	48.65	40.54	34.75	30.41	27.03	24.33
900	62.16	4.32E-03	3.45E-03	2.88E-03	2.47E-03	2.16E-03	1.92E-03	1.73E-03
	16,420.41	68.42	54.73	45.61	39.10	34.21	30.41	27.37
1,000	69.07	4.80E-03	3.84E-03	3.20E-03	2.74E-03	2.40E-03	2.13E-03	1.92E-03
	18,244.90	76.02	60.82	50.68	43.44	38.01	33.79	30.41
1,500	103.60	7.19E-03	5.76E-03	4.80E-03	4.11E-03	3.60E-03	3.20E-03	2.88E-03
	27,367.35	114.03	91.22	76.02	65.16	57.02	50.68	45.61
2,000	138.13	9.59E-03	7.67E-03	6.39E-03	5.48E-03	4.80E-03	4.26E-03	3.84E-03
	36,489.80	152.04	121.63	101.36	86.88	76.02	67.57	60.82
2,500	172.66	0.01	9.59E-03	7.99E-03	6.85E-03	6.00E-03	5.33E-03	4.80E-03
	45,612.25	190.05	152.04	126.70	108.60	95.03	84.47	76.02
3,000	207.20	0.01	0.01	9.59E-03	8.22E-03	7.19E-03	6.39E-03	5.76E-03
	54,734.70	228.06	182.45	152.04	130.32	114.03	101.36	91.22
3,500	241.73	0.02	0.01	0.01	9.59E-03	8.39E-03	7.46E-03	6.71E-03
	63,857.15	266.07	212.86	177.38	152.04	133.04	118.25	106.43
4,000	276.26	0.02	0.02	0.01	0.01	9.59E-03	8.53E-03	7.67E-03
	72,979.60	304.08	243.27	202.72	173.76	152.04	135.15	121.63
4,500	310.79	0.02	0.02	0.01	0.01	0.01	9.59E-03	8.63E-03
	82,102.05	342.09	273.67	228.06	195.48	171.05	152.04	136.84
5,000	345.33	0.02	0.02	0.02	0.01	0.01	0.01	9.59E-03
	91,224.51	380.10	304.08	253.40	217.20	190.05	168.93	152.04
5,500	379.86	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	100,346.96	418.11	334.49	278.74	238.92	209.06	185.83	167.24
6,000	414.39	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	109,469.41	456.12	364.90	304.08	260.64	228.06	202.72	182.45
6,500	448.92	0.03	0.02	0.02	0.02	0.02	0.01	0.01
	145,181.23	494.13	395.31	329.42	282.36	247.07	219.61	197.65
7,000	483.46	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	127,714.31	532.14	425.71	354.76	304.08	266.07	236.51	212.86
7,500	517.99	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	136,836.76	570.15	456.12	380.10	325.80	285.08	253.40	228.06
8,000	552.52	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	145,959.21	608.16	486.53	405.44	347.52	304.08	270.29	243.27
8,500	587.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	155,081.66	646.17	516.94	430.78	369.24	323.09	287.19	258.47

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Peterborough Airport						
		Discharge Rate for following Retention Periods						
		4 hr	**5 hr**	**6 hr**	**7 hr**	**8 hr**	**9 hr**	**10 hr**
	(m^3)	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**
	(gal)	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***	***(gal/min)***
100	7.59	5.27E-04	4.22E-04	3.51E-04	3.01E-04	2.64E-04	2.34E-04	2.11E-04
	2,005.18	*8.35*	*6.68*	*5.57*	*4.77*	*4.18*	*3.71*	*3.34*
200	15.18	1.05E-03	8.43E-04	7.03E-04	6.02E-04	5.27E-04	4.69E-04	4.22E-04
	4,010.36	*16.71*	*13.37*	*11.14*	*9.55*	*8.35*	*7.43*	*6.68*
300	22.77	1.58E-03	1.27E-03	1.05E-03	9.04E-04	7.91E-04	7.03E-04	6.33E-04
	6,015.55	*25.06*	*20.05*	*16.71*	*14.32*	*12.53*	*11.14*	*10.03*
400	30.36	2.11E-03	1.69E-03	1.41E-03	1.20E-03	1.05E-03	9.37E-04	8.43E-04
	8,020.73	*33.42*	*26.74*	*22.28*	*19.10*	*16.71*	*14.85*	*13.37*
500	37.95	2.64E-03	2.11E-03	1.76E-03	1.51E-03	1.32E-03	1.17E-03	1.05E-03
	10,025.91	*41.77*	*33.42*	*27.85*	*23.87*	*20.89*	*18.57*	*16.71*
600	45.54	3.16E-03	2.53E-03	2.11E-03	1.81E-03	1.58E-03	1.41E-03	1.27E-03
	12,031.09	*50.13*	*40.10*	*33.42*	*28.65*	*25.06*	*22.28*	*20.05*
700	53.13	3.69E-03	2.95E-03	2.46E-03	2.11E-03	1.84E-03	1.64E-03	1.48E-03
	14,036.28	*58.48*	*46.79*	*38.99*	*33.42*	*29.24*	*25.99*	*23.39*
800	60.72	4.22E-03	3.37E-03	2.81E-03	2.41E-03	2.11E-03	1.87E-03	1.69E-03
	16,041.46	*66.84*	*53.47*	*44.56*	*38.19*	*33.42*	*29.71*	*26.74*
900	68.31	4.74E-03	3.80E-03	3.16E-03	2.71E-03	2.37E-03	2.11E-03	1.90E-03
	18,046.64	*75.19*	*60.16*	*50.13*	*42.97*	*37.60*	*33.42*	*30.08*
1,000	75.91	5.27E-03	4.22E-03	3.51E-03	3.01E-03	2.64E-03	2.34E-03	2.11E-03
	20,051.82	*83.55*	*66.84*	*55.70*	*47.74*	*41.77*	*37.13*	*33.42*
1,500	113.86	7.91E-03	6.33E-03	5.27E-03	4.52E-03	3.95E-03	3.51E-03	3.16E-03
	30,077.74	*125.32*	*100.26*	*83.55*	*71.61*	*62.66*	*55.70*	*50.13*
2,000	151.81	0.01	8.43E-03	7.03E-03	6.02E-03	5.27E-03	4.69E-03	4.22E-03
	40,103.65	*167.10*	*133.68*	*111.40*	*95.48*	*83.55*	*74.27*	*66.84*
2,500	189.76	0.01	0.01	8.79E-03	7.53E-03	6.59E-03	5.86E-03	5.27E-03
	50,129.56	*208.87*	*167.10*	*139.25*	*119.36*	*104.44*	*92.83*	*83.55*
3,000	227.72	0.02	0.01	0.01	9.04E-03	7.91E-03	7.03E-03	6.33E-03
	60,155.47	*250.65*	*200.52*	*167.10*	*143.23*	*125.32*	*111.40*	*100.26*
3,500	265.67	0.02	0.01	0.01	0.01	9.22E-03	8.20E-03	7.38E-03
	70,181.38	*292.42*	*233.94*	*194.95*	*167.10*	*146.21*	*129.97*	*116.97*
4,000	303.62	0.02	0.02	0.01	0.01	0.01	9.37E-03	8.43E-03
	80,207.30	*334.20*	*267.36*	*222.80*	*190.97*	*167.10*	*148.53*	*133.68*
4,500	341.57	0.02	0.02	0.02	0.01	0.01	0.01	9.49E-03
	90,233.21	*375.97*	*300.78*	*250.65*	*214.84*	*187.99*	*167.10*	*150.39*
5,000	379.53	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	100,259.12	*417.75*	*334.20*	*278.50*	*238.71*	*208.87*	*185.67*	*167.10*
5,500	417.48	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	110,285.03	*459.52*	*367.62*	*306.35*	*262.58*	*229.76*	*204.23*	*183.81*
6,000	455.43	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	120,310.94	*501.30*	*401.04*	*334.20*	*286.45*	*250.65*	*222.80*	*200.52*
6,500	493.38	0.03	0.03	0.02	0.02	0.02	0.02	0.01
	130,336.86	*543.07*	*434.46*	*362.05*	*310.33*	*271.54*	*241.36*	*217.23*
7,000	531.34	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	140,362.77	*584.84*	*467.88*	*389.90*	*334.20*	*292.42*	*259.93*	*233.94*
7,500	569.29	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	150,388.68	*626.62*	*501.30*	*417.75*	*358.07*	*313.31*	*278.50*	*250.65*
8,000	607.24	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	160,414.59	*668.39*	*534.72*	*445.60*	*381.94*	*334.20*	*297.06*	*267.36*
8,500	645.19	0.04	0.04	0.03	0.03	0.02	0.02	0.02
	170,440.50	*710.17*	*568.14*	*473.45*	*405.81*	*355.08*	*315.63*	*284.07*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Storage/ Settling Volume*	Port Colbourne						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m^3)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	9.16	6.36E-04	5.09E-04	4.24E-04	3.63E-04	3.18E-04	2.83E-04	2.54E-04
	2,419.27	*10.08*	*8.06*	*6.72*	*5.76*	*5.04*	*4.48*	*4.03*
200	18.32	1.27E-03	1.02E-03	8.48E-04	7.27E-04	6.36E-04	5.65E-04	5.09E-04
	4,838.54	*20.16*	*16.13*	*13.44*	*11.52*	*10.08*	*8.96*	*8.06*
300	27.47	1.91E-03	1.53E-03	1.27E-03	1.09E-03	9.54E-04	8.48E-04	7.63E-04
	7,257.81	*30.24*	*24.19*	*20.16*	*17.28*	*15.12*	*13.44*	*12.10*
400	36.63	2.54E-03	2.04E-03	1.70E-03	1.45E-03	1.27E-03	1.13E-03	1.02E-03
	9,677.08	*40.32*	*32.26*	*26.88*	*23.04*	*20.16*	*17.92*	*16.13*
500	45.79	3.18E-03	2.54E-03	2.12E-03	1.82E-03	1.59E-03	1.41E-03	1.27E-03
	12,096.34	*50.40*	*40.32*	*33.60*	*28.80*	*25.20*	*22.40*	*20.16*
600	54.95	3.82E-03	3.05E-03	2.54E-03	2.18E-03	1.91E-03	1.70E-03	1.53E-03
	14,515.61	*60.48*	*48.39*	*40.32*	*34.56*	*30.24*	*26.88*	*24.19*
700	64.11	4.45E-03	3.56E-03	2.97E-03	2.54E-03	2.23E-03	1.98E-03	1.78E-03
	16,934.88	*70.56*	*56.45*	*47.04*	*40.32*	*35.28*	*31.36*	*28.22*
800	73.26	5.09E-03	4.07E-03	3.39E-03	2.91E-03	2.54E-03	2.26E-03	2.04E-03
	19,354.15	*80.64*	*64.51*	*53.76*	*46.08*	*40.32*	*35.84*	*32.26*
900	82.42	5.72E-03	4.58E-03	3.82E-03	3.27E-03	2.86E-03	2.54E-03	2.29E-03
	21,773.42	*90.72*	*72.58*	*60.48*	*51.84*	*45.36*	*40.32*	*36.29*
1,000	91.58	6.36E-03	5.09E-03	4.24E-03	3.63E-03	3.18E-03	2.83E-03	2.54E-03
	24,192.69	*100.80*	*80.64*	*67.20*	*57.60*	*50.40*	*44.80*	*40.32*
1,500	137.37	9.54E-03	7.63E-03	6.36E-03	5.45E-03	4.77E-03	4.24E-03	3.82E-03
	36,289.03	*151.20*	*120.96*	*100.80*	*86.40*	*75.60*	*67.20*	*60.48*
2,000	183.16	0.01	0.01	8.48E-03	7.27E-03	6.36E-03	5.65E-03	5.09E-03
	48,385.38	*201.61*	*161.28*	*134.40*	*115.20*	*100.80*	*89.60*	*80.64*
2,500	228.95	0.02	0.01	0.01	9.09E-03	7.95E-03	7.07E-03	6.36E-03
	60,481.72	*252.01*	*201.61*	*168.00*	*144.00*	*126.00*	*112.00*	*100.80*
3,000	274.74	0.02	0.02	0.01	0.01	9.54E-03	8.48E-03	7.63E-03
	72,578.07	*302.41*	*241.93*	*201.61*	*172.80*	*151.20*	*134.40*	*120.96*
3,500	320.53	0.02	0.02	0.01	0.01	0.01	9.89E-03	8.90E-03
	84,674.41	*352.81*	*282.25*	*235.21*	*201.61*	*176.41*	*156.80*	*141.12*
4,000	366.32	0.03	0.02	0.02	0.01	0.01	0.01	0.01
	96,770.75	*403.21*	*322.57*	*268.81*	*230.41*	*201.61*	*179.21*	*161.28*
4,500	412.11	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	108,867.10	*453.61*	*362.89*	*302.41*	*259.21*	*226.81*	*201.61*	*181.45*
5,000	457.90	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	120,963.44	*504.01*	*403.21*	*336.01*	*288.01*	*252.01*	*224.01*	*201.61*
5,500	503.69	0.03	0.03	0.02	0.02	0.02	0.02	0.01
	133,059.79	*554.42*	*443.53*	*369.61*	*316.81*	*277.21*	*246.41*	*221.77*
6,000	549.48	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	145,156.13	*604.82*	*483.85*	*403.21*	*345.61*	*302.41*	*268.81*	*241.93*
6,500	595.27	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	157,252.48	*655.22*	*524.17*	*436.81*	*374.41*	*327.61*	*291.21*	*262.09*
7,000	641.06	0.04	0.04	0.03	0.03	0.02	0.02	0.02
	169,348.82	*705.62*	*564.50*	*470.41*	*403.21*	*352.81*	*313.61*	*282.25*
7,500	686.85	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	181,445.16	*756.02*	*604.82*	*504.01*	*432.01*	*378.01*	*336.01*	*302.41*
8,000	732.64	0.05	0.04	0.03	0.03	0.03	0.02	0.02
	193,541.51	*806.42*	*645.14*	*537.62*	*460.81*	*403.21*	*358.41*	*322.57*
8,500	778.43	0.05	0.04	0.04	0.03	0.03	0.02	0.02
	205,637.85	*856.82*	*685.46*	*571.22*	*489.61*	*428.41*	*380.81*	*342.73*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m²)	Storage/ Settling Volume*	Brockville PCC						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m³)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	7.78	5.40E-04	4.32E-04	3.60E-04	3.09E-04	2.70E-04	2.40E-04	2.16E-04
	2,055.37	*8.56*	*6.85*	*5.71*	*4.89*	*4.28*	*3.81*	*3.43*
200	15.56	1.08E-03	8.65E-04	7.20E-04	6.18E-04	5.40E-04	4.80E-04	4.32E-04
	4,110.75	*17.13*	*13.70*	*11.42*	*9.79*	*8.56*	*7.61*	*6.85*
300	23.34	1.62E-03	1.30E-03	1.08E-03	9.26E-04	8.10E-04	7.20E-04	6.48E-04
	6,166.12	*25.69*	*20.55*	*17.13*	*14.68*	*12.85*	*11.42*	*10.28*
400	31.12	2.16E-03	1.73E-03	1.44E-03	1.24E-03	1.08E-03	9.61E-04	8.65E-04
	8,221.50	*34.26*	*27.40*	*22.84*	*19.57*	*17.13*	*15.22*	*13.70*
500	38.90	2.70E-03	2.16E-03	1.80E-03	1.54E-03	1.35E-03	1.20E-03	1.08E-03
	10,276.87	*42.82*	*34.26*	*28.55*	*24.47*	*21.41*	*19.03*	*17.13*
600	46.68	3.24E-03	2.59E-03	2.16E-03	1.85E-03	1.62E-03	1.44E-03	1.30E-03
	12,332.25	*51.38*	*41.11*	*34.26*	*29.36*	*25.69*	*22.84*	*20.55*
700	54.46	3.78E-03	3.03E-03	2.52E-03	2.16E-03	1.89E-03	1.68E-03	1.51E-03
	14,387.62	*59.95*	*47.96*	*39.97*	*34.26*	*29.97*	*26.64*	*23.98*
800	62.24	4.32E-03	3.46E-03	2.88E-03	2.47E-03	2.16E-03	1.92E-03	1.73E-03
	16,443.00	*68.51*	*54.81*	*45.67*	*39.15*	*34.26*	*30.45*	*27.40*
900	70.02	4.86E-03	3.89E-03	3.24E-03	2.78E-03	2.43E-03	2.16E-03	1.95E-03
	18,498.37	*77.08*	*61.66*	*51.38*	*44.04*	*38.54*	*34.26*	*30.83*
1,000	77.81	5.40E-03	4.32E-03	3.60E-03	3.09E-03	2.70E-03	2.40E-03	2.16E-03
	20,553.75	*85.64*	*68.51*	*57.09*	*48.94*	*42.82*	*38.06*	*34.26*
1,500	116.71	8.10E-03	6.48E-03	5.40E-03	4.63E-03	4.05E-03	3.60E-03	3.24E-03
	30,830.62	*128.46*	*102.77*	*85.64*	*73.41*	*64.23*	*57.09*	*51.38*
2,000	155.61	0.01	8.65E-03	7.20E-03	6.18E-03	5.40E-03	4.80E-03	4.32E-03
	41,107.49	*171.28*	*137.02*	*114.19*	*97.87*	*85.64*	*76.12*	*68.51*
2,500	194.51	0.01	0.01	9.01E-03	7.72E-03	6.75E-03	6.00E-03	5.40E-03
	51,384.37	*214.10*	*171.28*	*142.73*	*122.34*	*107.05*	*95.16*	*85.64*
3,000	233.42	0.02	0.01	0.01	9.26E-03	8.10E-03	7.20E-03	6.48E-03
	61,661.24	*256.92*	*205.54*	*171.28*	*146.81*	*128.46*	*114.19*	*102.77*
3,500	272.32	0.02	0.02	0.01	0.01	9.46E-03	8.40E-03	7.56E-03
	71,938.11	*299.74*	*239.79*	*199.83*	*171.28*	*149.87*	*133.22*	*119.90*
4,000	311.22	0.02	0.02	0.01	0.01	0.01	9.61E-03	8.65E-03
	82,214.99	*342.56*	*274.05*	*228.37*	*195.75*	*171.28*	*152.25*	*137.02*
4,500	350.12	0.02	0.02	0.02	0.01	0.01	0.01	9.73E-03
	92,491.86	*385.38*	*308.31*	*256.92*	*220.22*	*192.69*	*171.28*	*154.15*
5,000	389.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	102,768.73	*428.20*	*342.56*	*285.47*	*244.69*	*214.10*	*190.31*	*171.28*
5,500	427.93	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	113,045.61	*471.02*	*376.82*	*314.02*	*269.16*	*235.51*	*209.34*	*188.41*
6,000	466.83	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	123,322.48	*513.84*	*411.07*	*342.56*	*293.62*	*256.92*	*228.37*	*205.54*
6,500	505.73	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	133,599.35	*556.66*	*445.33*	*371.11*	*318.09*	*278.33*	*247.41*	*222.67*
7,000	544.64	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	143,876.23	*599.48*	*479.59*	*399.66*	*342.56*	*299.74*	*266.44*	*239.79*
7,500	583.54	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	154,153.10	*642.30*	*513.84*	*428.20*	*367.03*	*321.15*	*285.47*	*256.92*
8,000	622.44	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	164,429.97	*685.12*	*548.10*	*456.75*	*391.50*	*342.56*	*304.50*	*274.05*
8,500	661.34	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	174,706.85	*727.95*	*582.36*	*485.30*	*415.97*	*363.97*	*323.53*	*291.18*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m²)	Storage/ Settling Volume*	Ottawa Int. Airport						
		Discharge Rate for following Retention Periods						
		4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr
	(m³)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)
	(gal)	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*	*(gal/min)*
100	8.68	6.02E-04	4.82E-04	4.02E-04	3.44E-04	3.01E-04	2.68E-04	2.41E-04
	2,291.78	*9.55*	*7.64*	*6.37*	*5.46*	*4.77*	*4.24*	*3.82*
200	17.35	1.20E-03	9.64E-04	8.03E-04	6.89E-04	6.02E-04	5.36E-04	4.82E-04
	4,583.56	*19.10*	*15.28*	*12.73*	*10.91*	*9.55*	*8.49*	*7.64*
300	26.03	1.81E-03	1.45E-03	1.120E-03	1.03E-03	9.04E-04	8.03E-04	7.23E-04
	6,875.34	*28.65*	*22.92*	*19.10*	*16.37*	*14.32*	*12.73*	*11.46*
400	34.70	2.41E-03	1.93E-03	1.61E-03	1.38E-03	1.20E-03	1.07E-03	9.64E-04
	9,167.12	*38.20*	*30.56*	*25.46*	*21.83*	*19.10*	*16.98*	*15.28*
500	43.38	3.01E-03	2.41E-03	2.01E-03	1.72E-03	1.51E-03	1.34E-03	1.20E-03
	11,458.90	*47.75*	*38.20*	*31.83*	*27.28*	*23.87*	*21.22*	*19.10*
600	52.05	3.61E-03	2.89E-03	2.41E-03	2.07E-03	1.81E-03	1.61E-03	1.45E-03
	13,750.68	*57.29*	*45.84*	*38.20*	*32.74*	*28.65*	*25.46*	*22.92*
700	60.73	4.22E-03	3.37E-03	2.81E-03	2.41E-03	2.11E-03	1.87E-03	1.69E-03
	16,042.46	*66.84*	*53.47*	*44.56*	*38.20*	*33.42*	*29.71*	*26.74*
800	69.40	4.82E-03	3.86E-03	3.21E-03	2.75E-03	2.41E-03	2.14E-03	1.93E-03
	18,334.24	*76.39*	*61.11*	*50.93*	*43.65*	*38.20*	*33.95*	*30.56*
900	78.08	5.42E-03	4.34E-03	3.61E-03	3.10E-03	2.71E-03	2.41E-03	2.17E-03
	20,626.02	*85.94*	*68.75*	*57.29*	*49.11*	*42.97*	*38.20*	*34.38*
1,000	86.75	6.02E-03	4.82E-03	4.02E-03	3.44E-03	3.01E-03	2.68E-03	2.41E-03
	22,917.80	*95.49*	*76.39*	*63.66*	*54.57*	*47.75*	*42.44*	*38.20*
1,500	130.13	9.04E-03	7.23E-03	6.02E-03	5.16E-03	4.52E-03	4.02E-03	3.61E-03
	34,376.71	*143.24*	*114.59*	*95.49*	*81.85*	*71.62*	*63.66*	*57.29*
2,000	173.51	0.01	9.64E-03	8.03E-03	6.89E-03	6.02E-03	5.36E-03	4.82E-03
	45,835.61	*190.98*	*152.79*	*127.32*	*109.13*	*95.49*	*84.88*	*76.39*
2,500	216.89	0.02	0.01	0.01	8.61E-03	7.53E-03	6.69E-03	6.02E-03
	57,294.51	*238.73*	*190.98*	*159.15*	*136.42*	*119.36*	*106.10*	*95.49*
3,000	260.26	0.02	0.01	0.01	0.01	9.04E-03	8.03E-03	7.23E-03
	68,753.41	*286.47*	*229.18*	*190.98*	*163.70*	*143.24*	*127.32*	*114.59*
3,500	303.64	0.02	0.02	0.01	0.01	0.01	9.37E-03	8.43E-03
	80,212.31	*334.22*	*267.37*	*222.81*	*190.98*	*167.11*	*148.54*	*133.69*
4,000	347.02	0.02	0.02	0.02	0.01	0.01	0.01	9.64E-03
	91,671.22	*381.96*	*305.57*	*254.64*	*218.26*	*190.98*	*169.76*	*152.79*
4,500	390.39	0.03	0.02	0.02	0.02	0.01	0.01	0.01
	103,130.12	*429.71*	*343.77*	*286.47*	*245.55*	*214.85*	*190.98*	*171.88*
5,000	433.77	0.03	0.02	0.02	0.02	0.02	0.01	0.01
	114,589.02	*477.45*	*381.96*	*318.30*	*272.83*	*238.73*	*212.20*	*190.98*
5,500	477.15	0.03	0.03	0.02	0.02	0.02	0.01	0.01
	126,047.92	*525.20*	*420.16*	*350.13*	*300.11*	*262.60*	*233.42*	*210.08*
6,000	520.52	0.04	0.03	0.02	0.02	0.02	0.02	0.01
	137,506.83	*572.95*	*458.36*	*381.96*	*327.40*	*286.47*	*254.64*	*229.18*
6,500	563.90	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	148,965.73	*620.69*	*496.55*	*413.79*	*354.68*	*310.35*	*275.86*	*248.28*
7,000	607.28	0.04	0.03	0.03	0.02	0.02	0.02	0.02
	160,424.63	*668.44*	*534.75*	*445.62*	*381.96*	*334.22*	*297.08*	*267.37*
7,500	650.66	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	171,883.53	*716.18*	*572.95*	*477.45*	*409.25*	*358.09*	*318.30*	*286.47*
8,000	694.03	0.05	0.04	0.03	0.03	0.02	0.02	0.02
	183,342.43	*763.93*	*611.14*	*509.28*	*436.53*	*381.96*	*339.52*	*305.57*
8,500	737.41	0.05	0.04	0.03	0.03	0.03	0.02	0.02
	194,801.34	*811.67*	*649.34*	*541.11*	*463.81*	*405.84*	*360.74*	*324.67*

* Storage/settling volume calculated using 25-year/24-hour storm event rainfall amounts for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data."

Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Table 6.2 Minimum storage/settling volume required (m^3) and peak discharge rate (m^3/s) using rational method 25-year, 5-minute peak discharge rate

Area of runoff collection area (m^2)	Thunder Bay Airport		Sault Ste. Marie Airport		Windsor Airport	
	Storage Volume	**Peak Discharge Rate**	**Storage Volume**	**Peak Discharge Rate**	**Storage Volume**	**Peak Discharge Rate**
	(m^3)	**(m^3/s)**	**(m^3)**	**(m^3/s)**	**(m^3)**	**(m^3/s)**
	(gal)	***(gal/min)***	***(gal)***	***(gal/min)***	***(gal)***	***(gal/min)***
100	3.88	4.31E-03	3.79	4.21E-03	4.55	0.01
	1,023.92	*68.26*	*1,000.13*	*66.68*	*1,201.38*	*80.09*
200	7.75	0.01	7.57	0.01	9.10	0.01
	2,047.83	*136.52*	*2,000.26*	*133.35*	*2,402.76*	*160.18*
300	11.63	0.01	11.36	0.01	13.64	0.02
	3,071.75	*204.78*	*3,000.40*	*200.03*	*3,604.13*	*240.28*
400	15.50	0.02	15.14	0.02	18.19	0.02
	4,095.66	*273.04*	*4,000.53*	*266.70*	*4,805.51*	*320.37*
500	19.38	0.02	18.93	0.02	22.74	0.03
	5,119.58	*341.31*	*5,000.66*	*333.38*	*6,006.89*	*400.46*
600	23.26	0.03	22.72	0.03	27.29	0.03
	6,143.49	*409.57*	*6,000.79*	*400.05*	*7,208.27*	*480.55*
700	27.13	0.03	26.50	0.03	31.83	0.04
	7,167.41	*477.83*	*7,000.92*	*466.73*	*8,409.64*	*560.64*
800	31.01	0.03	30.29	0.03	36.38	0.04
	8,191.32	*546.09*	*8,001.05*	*533.40*	*9,611.02*	*640.73*
900	34.88	0.04	34.07	0.04	40.93	0.05
	9,215.24	*614.35*	*9,001.19*	*600.08*	*10,812.40*	*720.83*
1,000	38.76	0.04	37.86	0.04	45.48	0.05
	10,239.15	*682.61*	*10,001.32*	*666.75*	*12,013.78*	*800.92*
1,500	58.14	0.06	56.79	0.06	68.22	0.08
	15,358.73	*1,023.92*	*15,001.98*	*1,000.13*	*18,020.67*	*1,201.38*
2,000	77.52	0.09	75.72	0.08	90.95	0.10
	20,478.31	*1,365.22*	*20,002.64*	*1,333.51*	*24,027.56*	*1,601.84*
2,500	96.90	0.11	94.65	0.11	113.69	0.13
	25,597.88	*1,706.53*	*25,003.29*	*1,666.89*	*30,034.44*	*2,002.30*
3,000	116.28	0.13	113.58	0.13	136.43	0.15
	30,717.46	*2,047.83*	*30,003.95*	*2,000.26*	*36,041.33*	*2,402.76*
3,500	135.66	0.15	132.51	0.15	159.17	0.18
	35,837.04	*2,389.14*	*35,004.61*	*2,333.64*	*42,048.22*	*2,803.21*
4,000	155.04	0.17	151.44	0.17	181.91	0.20
	40,956.62	*2,730.44*	*40,005.27*	*2,667.02*	*48,055.11*	*3,203.67*
4,500	174.42	0.19	170.37	0.19	204.65	0.23
	46,076.19	*3,071.75*	*45,005.93*	*3,000.40*	*54,062.00*	*3,604.13*
5,000	193.80	0.22	189.30	0.21	227.39	0.25
	51,195.77	*3,413.05*	*50,006.59*	*55.56*	*60,068.89*	*4,004.59*
5,500	213.18	0.24	208.23	0.23	250.13	0.28
	56,315.35	*3,754.36*	*55,007.25*	*3,667.15*	*66,075.78*	*4,405.05*
6,000	232.56	0.26	227.16	0.25	272.86	0.30
	61,434.92	*4,095.66*	*60,007.91*	*4,000.53*	*72,082.67*	*4,805.51*
6,500	251.94	0.28	246.09	0.27	295.60	0.33
	66,554.50	*4,436.97*	*65,008.57*	*4,333.90*	*78,089.56*	*5,205.97*
7,000	271.32	0.30	265.02	0.29	318.34	0.35
	71,674.08	*4,778.27*	*70,009.22*	*4,667.28*	*84,096.45*	*5,606.43*
7,500	290.70	0.32	283.95	0.32	341.08	0.38
	76,793.65	*5,119.58*	*75,009.88*	*5,000.66*	*90,103.33*	*6,006.89*
8,000	310.08	0.34	302.88	0.34	363.82	0.40
	81,913.23	*5,460.88*	*80,010.54*	*5,334.04*	*96,110.22*	*6,407.35*

* Storage/settling volume calculated using 25-year/5-minute storm event rainfall amounts over a 15-minute retention period for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data." Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m²)	Chatham WPCP		Owen Sound		Stratford MOE	
	Storage Volume	**Peak Discharge Rate**	**Storage Volume**	**Peak Discharge Rate**	**Storage Volume**	**Peak Discharge Rate**
	(m³)	**(m³/s)**	**(m³)**	**(m³/s)**	**(m³)**	**(m³/s)**
	(gal)	***(gal/min)***	***(gal)***	***(gal/min)***	***(gal)***	***(gal/min)***
100	4.24	4.71E-03	4.43	4.93E-03	3.99	0.00
	1,120.88	*74.73*	*1,171.50*	*78.10*	*1,053.19*	*70.21*
200	8.49	0.01	8.87	0.01	7.97	0.01
	2,241.76	*149.45*	*2,342.99*	*156.20*	*2,106.38*	*140.43*
300	12.73	0.01	13.30	0.01	11.96	0.01
	3,362.64	*224.18*	*3,514.49*	*234.30*	*3,159.56*	*210.64*
400	16.97	0.02	17.74	0.02	15.95	0.02
	4,483.52	*298.90*	*4,685.98*	*312.40*	*4,212.75*	*280.85*
500	21.22	0.02	22.17	0.02	19.93	0.02
	5,604.40	*373.63*	*5,857.48*	*390.50*	*5,265.94*	*351.06*
600	25.46	0.03	26.61	0.03	23.92	0.03
	6,725.28	*448.35*	*7,028.97*	*468.60*	*6,319.13*	*421.28*
700	29.70	0.03	31.04	0.03	27.91	0.03
	7,846.16	*523.08*	*8,200.47*	*546.70*	*7,372.31*	*491.49*
800	33.94	0.04	35.48	0.04	31.89	0.04
	8,967.04	*597.80*	*9,371.97*	*624.80*	*8,425.50*	*561.70*
900	38.19	0.04	39.91	0.04	35.88	0.04
	10,087.91	*672.53*	*10,543.46*	*702.90*	*9,478.69*	*631.91*
1,000	42.43	0.05	44.35	0.05	39.87	0.04
	11,208.79	*747.25*	*11,714.96*	*781.00*	*10,531.88*	*702.13*
1,500	63.65	0.07	66.52	0.07	59.80	0.07
	16,813.19	*1,120.88*	*17,572.44*	*1,171.50*	*15,797.81*	*1,053.19*
2,000	84.86	0.09	88.69	0.10	79.74	0.09
	22,417.59	*1,494.51*	*23,429.92*	*1,561.99*	*21,063.75*	*1,404.25*
2,500	106.08	0.12	110.87	0.12	99.67	0.11
	28,021.98	*1,868.13*	*29,287.40*	*1,952.49*	*26,329.69*	*1,755.31*
3,000	127.29	0.14	133.04	0.15	119.60	0.13
	33,626.38	*2,241.76*	*35,144.87*	*2,342.99*	*31,595.63*	*2,106.38*
3,500	148.51	0.17	155.21	0.17	139.54	0.16
	39,230.78	*2,615.39*	*41,002.35*	*2,733.49*	*36,861.56*	*2,457.44*
4,000	169.72	0.19	177.39	0.20	159.47	0.18
	44,835.18	*2,989.01*	*46,859.83*	*3,123.99*	*42,127.50*	*2,808.50*
4,500	190.94	0.21	199.56	0.22	179.41	0.20
	50,439.57	*3,362.64*	*52,717.31*	*3,514.49*	*47,393.44*	*3,159.56*
5,000	212.15	0.24	221.73	0.25	199.34	0.22
	56,043.97	*3,736.26*	*58,574.79*	*3,904.99*	*52,659.38*	*3,510.63*
5,500	233.37	0.26	243.90	0.27	219.27	0.24
	61,648.37	*4,109.89*	*64,432.27*	*4,295.48*	*57,925.31*	*3,861.69*
6,000	254.58	0.28	266.08	0.30	239.21	0.27
	67,252.76	*4,483.52*	*70,289.75*	*4,685.98*	*63,191.25*	*4,212.75*
6,500	275.80	0.31	288.25	0.32	259.14	0.29
	72,857.16	*4,857.14*	*76,147.23*	*5,076.48*	*68,457.19*	*4,563.81*
7,000	297.01	0.33	310.42	0.34	279.07	0.31
	78,461.56	*5,230.77*	*82,004.71*	*5,466.98*	*73,723.13*	*4,914.88*
7,500	318.23	0.35	332.60	0.37	299.01	0.33
	84,065.95	*5,604.40*	*87,862.19*	*5,857.48*	*78,989.07*	*5,265.94*
8,000	339.44	0.38	354.77	0.39	318.94	0.35
	89,670.35	*5,978.02*	*93,719.66*	*6,247.98*	*84,255.00*	*5,617.00*

* Storage/settling volume calculated using 25-year/5-minute storm event rainfall amounts over a 15-minute retention period for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data." Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m²)	Brantford MOE		Guelph Arboretum		Hamilton Airport	
	Storage Volume	**Peak Discharge Rate**	**Storage Volume**	**Peak Discharge Rate**	**Storage Volume**	**Peak Discharge Rate**
	(m³)	**(m³/s)**	**(m³)**	**(m³/s)**	**(m³)**	**(m³/s)**
	(gal)	***(gal/min)***	***(gal)***	***(gal/min)***	***(gal)***	***(gal/min)***
100	3.69	4.10E-03	4.30	4.77E-03	4.61	0.01
	974.52	*64.97*	*1,134.91*	*75.66*	*1,217.84*	*81.19*
200	7.38	0.01	8.59	0.01	9.22	0.01
	1,949.04	*129.94*	*2,269.81*	*151.32*	*2,435.69*	*162.38*
300	11.07	0.01	12.89	0.01	13.83	0.02
	2,923.56	*194.90*	*3,404.72*	*226.98*	*3,653.53*	*243.57*
400	14.76	0.02	17.18	0.02	18.44	0.02
	3,898.07	*259.87*	*4,539.62*	*302.64*	*4,871.37*	*324.76*
500	18.44	0.02	21.48	0.02	23.05	0.03
	4,872.59	*324.84*	*5,674.53*	*378.30*	*6,089.22*	*405.95*
600	22.13	0.02	25.78	0.03	27.66	0.03
	5,847.11	*389.81*	*6,809.43*	*453.96*	*7,307.06*	*487.14*
700	25.82	0.03	30.07	0.03	32.27	0.04
	6,821.63	*454.78*	*7,944.34*	*529.62*	*8,524.90*	*568.33*
800	29.51	0.03	34.37	0.04	36.88	0.04
	7,796.15	*519.74*	*9,079.24*	*605.28*	*9,742.75*	*649.52*
900	33.20	0.04	38.67	0.04	41.49	0.05
	8,770.67	*584.71*	*10,214.15*	*680.94*	*10,960.59*	*730.71*
1,000	36.89	0.04	42.96	0.05	46.10	0.05
	9,745.19	*649.68*	*11,349.06*	*756.60*	*12,178.43*	*811.90*
1,500	55.33	0.06	64.44	0.07	69.15	0.08
	14,617.78	*974.52*	*17,023.58*	*1,134.91*	*18,267.65*	*1,217.84*
2,000	73.78	0.08	85.92	0.10	92.20	0.10
	19,490.37	*1,299.36*	*22,698.11*	*1,513.21*	*24,356.87*	*1,623.79*
2,500	92.22	0.10	107.40	0.12	115.25	0.13
	24,362.97	*1,624.20*	*28,372.64*	*1,891.51*	*30,446.08*	*2,029.74*
3,000	110.67	0.12	128.88	0.14	138.30	0.15
	29,235.56	*1,949.04*	*34,047.17*	*2,269.81*	*36,535.30*	*2,435.69*
3,500	129.11	0.14	150.36	0.17	161.35	0.18
	34,108.15	*2,273.88*	*39,721.70*	*2,648.11*	*42,624.52*	*2,841.63*
4,000	147.56	0.16	171.84	0.19	184.40	0.20
	38,980.75	*2,598.72*	*45,396.22*	*3,026.41*	*48,713.74*	*3,247.58*
4,500	166.00	0.18	193.33	0.21	207.45	0.23
	43,853.34	*2,923.56*	*51,070.75*	*3,404.72*	*54,802.95*	*3,653.53*
5,000	184.45	0.20	214.81	0.24	230.50	0.26
	48,725.93	*3,248.40*	*56,745.28*	*3,783.02*	*60,892.17*	*4,059.48*
5,500	202.89	0.23	236.29	0.26	253.55	0.28
	53,598.53	*3,573.24*	*62,419.81*	*4,161.32*	*66,981.39*	*4,465.43*
6,000	221.34	0.25	257.77	0.29	276.60	0.31
	58,471.12	*3,898.07*	*68,094.34*	*4,539.62*	*73,070.60*	*4,871.37*
6,500	239.78	0.27	279.25	0.31	299.65	0.33
	63,343.71	*4,222.91*	*73,768.87*	*4,917.92*	*79,159.82*	*5,277.32*
7,000	258.23	0.29	300.73	0.33	322.71	0.36
	68,216.30	*4,547.75*	*79,443.39*	*5,296.23*	*85,249.04*	*5,683.27*
7,500	276.67	0.31	322.21	0.36	345.76	0.38
	73,088.90	*4,872.59*	*85,117.92*	*5,674.53*	*91,338.25*	*6,089.22*
8,000	295.12	0.33	343.69	0.38	368.81	0.41
	77,961.49	*5,197.43*	*90,792.45*	*6,052.83*	*97,427.47*	*6,495.16*

* Storage/settling volume calculated using 25-year/5-minute storm event rainfall amounts over a 15-minute retention period for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data." Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Toronto Pearson Int. Airport		Barrie WPCP		Oshawa WPCP	
	Storage Volume	Peak Discharge Rate	Storage Volume	Peak Discharge Rate	Storage Volume	Peak Discharge Rate
	(m^3)	(m^3/s)	(m^3)	(m^3/s)	(m^3)	(m^3/s)
	(gal)	*(gal/min)*	*(gal)*	*(gal/min)*	*(gal)*	*(gal/min)*
100	4.45	4.94E-03	4.13	4.59E-03	3.17	3.52E-03
	1,175.15	*78.34*	*1,091.61*	*72.77*	*837.92*	*55.86*
200	8.90	0.01	8.26	0.01	6.34	0.01
	2,350.31	*156.69*	*2,183.21*	*145.55*	*1,675.83*	*111.72*
300	13.35	0.01	12.40	0.01	9.52	0.01
	3,525.46	*235.03*	*3,274.82*	*218.32*	*2,513.75*	*167.58*
400	17.79	0.02	16.53	0.02	12.69	0.01
	4,700.62	*313.37*	*4,366.43*	*291.10*	*3,351.66*	*223.44*
500	22.24	0.02	20.66	0.02	15.86	0.02
	5,875.77	*391.72*	*5,458.04*	*363.87*	*4,189.58*	*279.31*
600	26.69	0.03	24.79	0.03	19.03	0.02
	7,050.93	*470.06*	*6,549.64*	*436.64*	*5,027.49*	*335.17*
700	31.14	0.03	28.93	0.03	22.20	0.02
	8,226.08	*548.41*	*7,641.25*	*509.42*	*5,865.41*	*391.03*
800	35.59	0.04	33.06	0.04	25.38	0.03
	9,401.24	*626.75*	*8,732.86*	*582.19*	*6,703.32*	*446.89*
900	40.04	0.04	37.19	0.04	28.55	0.03
	10,576.39	*705.09*	*9,824.47*	*654.96*	*7,541.24*	*502.75*
1,000	44.48	0.05	41.32	0.05	31.72	0.04
	11,751.55	*783.44*	*10,916.07*	*727.74*	*8,379.15*	*558.61*
1,500	66.73	0.07	61.98	0.07	47.58	0.05
	17,627.32	*1,175.15*	*16,374.11*	*1,091.61*	*12,568.73*	*837.92*
2,000	88.97	0.10	82.64	0.09	63.44	0.07
	23,503.10	*1,566.87*	*21,832.14*	*1,455.48*	*16,758.31*	*1,117.22*
2,500	111.21	0.12	103.31	0.11	79.30	0.09
	29,378.87	*1,958.59*	*27,290.18*	*1,819.35*	*20,947.88*	*1,396.53*
3,000	133.45	0.15	123.97	0.14	95.16	0.11
	35,254.64	*2,350.31*	*32,748.22*	*2,183.21*	*25,137.46*	*1,675.83*
3,500	155.70	0.17	144.63	0.16	111.02	0.12
	41,130.42	*2,742.03*	*38,206.25*	*2,547.08*	*29,327.03*	*1,955.14*
4,000	177.94	0.20	165.29	0.18	126.88	0.14
	47,006.19	*3,133.75*	*43,664.29*	*2,910.95*	*33,516.61*	*2,234.44*
4,500	200.18	0.22	185.95	0.21	142.73	0.16
	52,881.97	*3,525.46*	*49,122.33*	*3,274.82*	*37,706.19*	*2,513.75*
5,000	222.42	0.25	206.61	0.23	158.59	0.18
	58,757.74	*3,917.18*	*54,580.36*	*3,638.69*	*41,895.76*	*2,793.05*
5,500	244.67	0.27	227.27	0.25	174.45	0.19
	64,633.52	*4,308.90*	*60,038.40*	*4,002.56*	*46,085.34*	*3,072.36*
6,000	266.91	0.30	247.93	0.28	190.31	0.21
	70,509.29	*4,700.62*	*65,496.43*	*4,366.43*	*50,274.92*	*3,351.66*
6,500	289.15	0.32	268.59	0.30	206.17	0.23
	76,385.06	*5,092.34*	*70,954.47*	*4,730.30*	*54,464.49*	*3,630.97*
7,000	311.39	0.35	289.26	0.32	222.03	0.25
	82,260.84	*5,484.06*	*76,412.51*	*5,094.17*	*58,654.07*	*3,910.27*
7,500	333.64	0.37	309.92	0.34	237.89	0.26
	88,136.61	*5,875.77*	*81,870.54*	*5,458.04*	*62,843.65*	*4,189.58*
8,000	355.88	0.40	330.58	0.37	253.75	0.28
	94,012.39	*6,267.49*	*87,328.58*	*5,821.91*	*67,033.22*	*4,468.88*

* Storage/settling volume calculated using 25-year/5-minute storm event rainfall amounts over a 15-minute retention period for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data." Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Area of runoff collection area (m^2)	Peterborough Airport		Port Colbourne		Brockville PCC		Ottawa Int. Airport	
	Storage Volume	Peak Discharge Rate	Storage Volume	Peak Discharge Rate	Storage Volume	Peak Discharge Rate	Storage Volume	Peak Discharge Rate
	(m^3)	(m^3/s)	(m^3)	(m^3/s)	(m^3)	(m^3/s)	(m^3)	(m^3/s)
	(gal)	*(gal/min)*	*(gal)*	*(gal/min)*	*(gal)*	*(gal/min)*	*(gal)*	*(gal/min)*
100	4.08	4.53E-03	3.50	3.89E-03	4.24	4.71E-03	4.91	0.01
	1,078.19	*71.88*	*924.51*	*61.63*	*1,119.05*	*74.60*	*1,297.67*	*86.51*
200	8.16	0.01	7.00	0.01	8.47	0.01	9.82	0.01
	2,156.38	*143.76*	*1,849.02*	*123.27*	*2,238.10*	*149.21*	*2,595.34*	*173.02*
300	12.24	0.01	10.50	0.01	12.71	0.01	14.74	0.02
	3,234.57	*215.64*	*2,773.54*	*184.90*	*3,357.15*	*223.81*	*3,893.01*	*259.53*
400	16.33	0.02	14.00	0.02	16.94	0.02	19.65	0.02
	4,312.76	*287.52*	*3,698.05*	*246.54*	*4,476.20*	*298.41*	*5,190.68*	*346.05*
500	20.41	0.02	17.50	0.02	21.18	0.02	24.56	0.03
	5,390.95	*359.40*	*4,622.56*	*308.17*	*5,595.25*	*373.02*	*6,488.35*	*432.56*
600	24.49	0.03	21.00	0.02	25.42	0.03	29.47	0.03
	6,469.15	*431.28*	*5,547.07*	*369.80*	*6,714.30*	*447.62*	*7,786.03*	*519.07*
700	28.57	0.03	24.50	0.03	29.65	0.03	34.39	0.04
	7,547.34	*503.16*	*6,471.58*	*431.44*	*7,833.35*	*522.22*	*9,083.70*	*605.58*
800	32.65	0.04	28.00	0.03	33.89	0.04	39.30	0.04
	8,625.53	*575.04*	*7,396.10*	*493.07*	*8,952.40*	*596.83*	*10,381.37*	*692.09*
900	36.73	0.04	31.50	0.03	38.12	0.04	44.21	0.05
	9,703.72	*646.91*	*8,320.61*	*554.71*	*10,071.45*	*671.43*	*11,679.04*	*778.60*
1,000	40.81	0.05	35.00	0.04	42.36	0.05	49.12	0.05
	10,781.91	*718.79*	*9,245.12*	*616.34*	*11,190.50*	*746.03*	*12,976.71*	*865.11*
1,500	61.22	0.07	52.50	0.06	63.54	0.07	73.68	0.08
	16,172.86	*1,078.19*	*13,867.68*	*924.51*	*16,785.75*	*1,119.05*	*19,465.06*	*1,297.67*
2,000	81.63	0.09	69.99	0.08	84.72	0.09	98.25	0.11
	21,563.82	*1,437.59*	*18,490.24*	*1,232.68*	*22,381.00*	*1,492.07*	*25,953.42*	*1,730.23*
2,500	102.04	0.11	87.49	0.10	105.90	0.12	122.81	0.14
	26,954.77	*1,796.98*	*23,112.80*	*1,540.85*	*27,976.25*	*1,865.08*	*32,441.77*	*2,162.78*
3,000	122.44	0.14	104.99	0.12	127.08	0.14	147.37	0.16
	32,345.73	*2,156.38*	*27,735.36*	*1,849.02*	*33,571.50*	*2,238.10*	*38,930.13*	*2,595.34*
3,500	142.85	0.16	122.49	0.14	148.26	0.16	171.93	0.19
	37,736.68	*2,515.78*	*32,357.92*	*2,157.19*	*39,166.75*	*2,611.12*	*45,418.48*	*3,027.90*
4,000	163.26	0.18	139.99	0.16	169.44	0.19	196.49	0.22
	43,127.63	*2,875.18*	*36,980.48*	*2,465.37*	*44,762.00*	*2,984.13*	*51,906.84*	*3,460.46*
4,500	183.66	0.20	157.49	0.17	190.62	0.21	221.05	0.25
	48,518.59	*3,234.57*	*41,603.04*	*2,773.54*	*50,357.24*	*3,357.15*	*58,395.19*	*3,893.01*
5,000	204.07	0.23	174.98	0.19	211.80	0.24	245.61	0.27
	53,909.54	*3,593.97*	*46,225.60*	*3,081.71*	*55,952.49*	*3,730.17*	*64,883.55*	*4,325.57*
5,500	224.48	0.25	192.48	0.21	232.99	0.26	270.17	0.30
	59,300.50	*3,953.37*	*50,848.16*	*3,389.88*	*61,547.74*	*4,103.18*	*71,371.90*	*4,758.13*
6,000	244.89	0.27	209.98	0.23	254.17	0.28	294.74	0.33
	64,691.45	*4,312.76*	*55,470.72*	*3,698.05*	*67,142.99*	*4,476.20*	*77,860.26*	*5,190.68*
6,500	265.29	0.29	227.48	0.25	275.35	0.31	319.30	0.35
	70,082.40	*4,672.16*	*60,093.28*	*4,006.22*	*72,738.24*	*4,849.22*	*84,348.61*	*5,623.24*
7,000	285.70	0.32	244.98	0.27	296.53	0.33	343.86	0.38
	75,473.36	*5,031.56*	*64,715.84*	*4,314.39*	*78,333.49*	*5,222.23*	*90,836.97*	*6,055.80*
7,500	306.11	0.34	262.48	0.29	317.71	0.35	368.42	0.41
	80,864.31	*5,390.95*	*69,338.40*	*4,622.56*	*83,928.74*	*5,595.25*	*97,325.32*	*6,488.35*
8,000	326.51	0.36	279.97	0.31	338.89	0.38	392.98	0.44
	86,255.27	*5,750.35*	*73,960.96*	*4,930.73*	*89,523.99*	*5,968.27*	*103,813.68*	*6,920.91*

* Storage/settling volume calculated using 25-year/5-minute storm event rainfall amounts over a 15-minute retention period for selected Ontario centres obtained from Atmospheric Environment Service, Environment Canada "Rainfall Intensity-Duration Frequency (IDF) Data." Runoff coefficient of 95 per cent has been used, meaning that 95 per cent of the rainfall entering the runoff collection area can be expected to enter the VFS system.

Table 6.3 Infiltration area required based on saturated hydraulic conductivity of soil texture classes

Discharge Rate to Infiltration Area		Infiltration Area Required Based on Saturated Hydraulic Conductivity of the Following Soil Texture Classes*					
		Sand		Loamy Sand		Sandy Loam	
m^3/s	gal/min	m^2	ft^2	m^2	ft^2	m^2	ft^2
1.00E-04	1.59	1.71	18.45	5.89	63.44	13.90	149.63
2.00E-04	3.17	3.43	36.91	11.79	126.88	27.80	299.25
3.00E-04	4.76	5.14	55.36	17.68	190.33	41.70	448.88
4.00E-04	6.34	6.86	73.81	23.58	253.77	55.60	598.51
5.00E-04	7.93	8.57	92.27	29.47	317.21	69.50	748.14
6.00E-04	9.51	10.29	110.72	35.36	380.65	83.40	897.76
7.00E-04	11.10	12.00	129.17	41.26	444.09	97.30	1,047.39
8.00E-04	12.68	13.71	147.62	47.15	507.54	111.20	1,197.02
9.00E-04	14.27	15.43	166.08	53.04	570.98	125.10	1,346.65
1.00E-03	15.85	17.14	184.53	58.94	634.42	139.00	1,496.27
1.50E-03	23.78	25.71	276.80	88.41	951.63	208.51	2,244.41
2.00E-03	31.70	34.29	369.06	117.88	1,268.84	278.01	2,992.55
2.50E-03	39.63	42.86	461.33	147.34	1,586.05	347.51	3,740.69
3.00E-03	47.55	51.43	553.59	176.81	1,903.26	417.01	4,488.82
3.50E-03	55.48	60.00	645.86	206.28	2,220.47	486.52	5,236.96
4.00E-03	63.40	68.57	738.12	235.75	2,537.68	556.02	5,985.10
4.50E-03	71.33	77.14	830.39	265.22	2,854.89	625.52	6,733.24
5.00E-03	79.25	85.71	922.65	294.69	3,172.10	695.02	7,481.37
5.50E-03	87.18	94.29	1,014.92	324.16	3,489.31	764.53	8,229.51
6.00E-03	95.10	102.86	1,107.18	353.63	3,806.52	834.03	8,977.65
6.50E-03	103.03	111.43	1,199.45	383.10	4,123.73	903.53	9,725.79
7.00E-03	110.95	120.00	1,291.71	412.57	4,440.94	973.03	10,473.92
7.50E-03	118.88	128.57	1,383.98	442.03	4,758.15	1,042.54	11,222.06
8.00E-03	126.80	137.14	1,476.24	471.50	5,075.36	1,112.04	11,970.20
8.50E-03	134.73	145.72	1,568.51	500.97	5,392.57	1,181.54	12,718.33
9.00E-03	142.65	154.29	1,660.77	530.44	5,709.78	1,251.04	13,466.47
9.50E-03	150.58	162.86	1,753.04	559.91	6,026.99	1,320.54	14,214.61
0.01	158.50	171.43	1,845.30	589.38	6,344.20	1,390.05	14,962.75
0.02	237.75	257.14	2,767.95	884.07	9,516.30	2,085.07	22,444.12
0.02	317.00	342.86	3,690.60	1,178.76	12,688.40	2,780.09	29,925.49
0.03	396.26	428.57	4,613.25	1,473.45	15,860.49	3,475.12	37,406.87
0.03	475.51	514.29	5,535.91	1,768.14	19,032.59	4,170.14	44,888.24
0.04	554.76	600.00	6,458.56	2,062.83	22,204.69	4,865.17	52,369.61
0.04	634.01	685.72	7,381.21	2,357.52	25,376.79	5,560.19	59,850.99
0.05	713.26	771.43	8,303.86	2,652.21	28,548.89	6,255.21	67,332.36
0.05	792.51	857.15	9,226.51	2,946.90	31,720.99	6,950.24	74,813.73
0.06	871.76	942.86	10,149.16	3,241.59	34,893.09	7,645.26	82,295.11
0.06	951.01	1,028.58	11,071.81	3,536.28	38,065.19	8,340.28	89,776.48
0.07	1,030.26	1,114.29	11,994.46	3,830.97	41,237.28	9,035.31	97,257.85
0.07	1,109.51	1,200.01	12,917.11	4,125.66	44,409.38	9,730.33	104,739.23
0.08	1,188.77	1,285.72	13,839.76	4,420.35	47,581.48	10,425.35	112,220.60
0.08	1,268.02	1,371.44	14,762.42	4,715.04	50,753.58	11,120.38	119,701.97
0.09	1,347.27	1,457.15	15,685.07	5,009.72	53,925.68	11,815.40	127,183.35
0.09	1,426.52	1,542.87	16,607.72	5,304.41	57,097.78	12,510.43	134,664.72
0.10	1,505.77	1,628.58	17,530.37	5,599.10	60,269.88	13,205.45	142,146.09
0.10	1,585.02	1,714.30	18,453.02	5,893.79	63,441.98	13,900.47	149,627.47
0.15	2,377.53	2,571.44	27,679.53	8,840.69	95,162.96	20,850.71	224,441.20
0.20	3,170.04	3,428.59	36,906.04	11,787.59	126,883.95	27,800.95	299,254.93
0.25	3,962.55	4,285.74	46,132.55	14,734.48	158,604.94	34,751.18	374,068.67
0.30	4,755.06	5,142.89	55,359.06	17,681.38	190,325.93	41,701.42	448,882.40
0.35	5,547.57	6,000.03	64,585.57	20,628.28	222,046.91	48,651.65	523,696.14
0.40	6,340.08	6857.18	73,812.08	23,575.18	253,767.90	55,601.89	598,509.87
0.45	7,132.59	7,714.33	83,038.59	26,522.07	285,488.89	62,552.13	673,323.60
0.50	7,925.10	8,571.48	92,265.10	29,468.95	317,209.88	69,502.31	748,137.34

* Soil texture class and typical hydraulic conductivity values under saturated soil conditions derived from Rawls et al (1982) for all textures except silt, which is taken from Carsel & Parrish (1988).

Discharge Rate to Infiltration Area		**Infiltration Area Required Based on Saturated Hydraulic Conductivity of the Following Soil Texture Classes***					
		Loam		**Silt**		**Silt Loam**	
m^3/s	*gal/min*	*m^2*	*ft^2*	*m^2*	*ft^2*	*m^2*	*ft^2*
1.00E-04	*1.59*	27.28	*293.62*	144.09	*1,551.04*	52.97	*570.14*
2.00E-04	*3.17*	54.56	*587.24*	288.18	*3,102.07*	105.93	*1,140.28*
3.00E-04	*4.76*	81.83	*880.87*	432.28	*4,653.11*	158.90	*1,710.41*
4.00E-04	*6.34*	109.11	*1,174.49*	576.37	*6,204.15*	211.86	*2,280.55*
5.00E-04	*7.93*	136.39	*1,468.11*	720.46	*7,755.19*	264.83	*2,850.69*
6.00E-04	*9.51*	163.67	*1,761.73*	864.55	*9,306.22*	317.80	*3,420.83*
7.00E-04	*11.10*	190.94	*2,055.36*	1,008.65	*10,857.26*	370.76	*3,990.96*
8.00E-04	*12.68*	218.22	*2,348.98*	1,152.74	*12,408.30*	423.73	*4,561.10*
9.00E-04	*14.27*	245.50	*2,642.60*	1,296.83	*13,959.34*	476.69	*5,131.24*
1.00E-03	*15.85*	272.78	*2,936.22*	1,440.92	*15,510.37*	529.66	*5,701.38*
1.50E-03	*23.78*	409.17	*4,404.34*	2,161.38	*23,265.56*	794.49	*8,552.07*
2.00E-03	*31.70*	545.55	*5,872.45*	2,881.84	*31,020.75*	1,059.32	*11,402.75*
2.50E-03	*39.63*	681.94	*7,340.56*	3,602.31	*38,775.94*	1,324.15	*14,253.44*
3.00E-03	*47.55*	818.33	*8,808.67*	4,322.77	*46,531.12*	1,588.98	*17,104.13*
3.50E-03	*55.48*	954.72	*10,276.79*	5,043.23	*54,286.31*	1,853.81	*19,954.82*
4.00E-03	*63.40*	1,091.11	*11,744.90*	5,763.69	*62,041.50*	2,118.64	*22,805.51*
4.50E-03	*71.33*	1,227.50	*13,213.01*	6,484.15	*69,796.69*	2,383.47	*25,656.20*
5.00E-03	*79.25*	1,363.88	*14,681.12*	7,204.61	*77,551.87*	2,648.31	*28,506.89*
5.50E-03	*87.18*	1,500.27	*16,149.24*	7,925.07	*85,307.06*	2,913.14	*31,357.57*
6.00E-03	*95.10*	1,636.66	*17,617.35*	8,645.53	*93,062.25*	3,177.97	*34,208.26*
6.50E-03	*103.03*	1,773.05	*19,085.46*	9,365.99	*100,817.44*	3,442.80	*37,058.95*
7.00E-03	*110.95*	1,909.44	*20,553.57*	10,086.46	*108,572.62*	3,707.63	*39,909.64*
7.50E-03	*118.88*	2,045.83	*22,021.69*	10,806.92	*116,327.81*	3,972.46	*42,760.33*
8.00E-03	*126.80*	2,182.21	*23,489.80*	11,527.38	*124,083.00*	4,237.29	*45,611.02*
8.50E-03	*134.73*	2,318.60	*24,957.91*	12,247.84	*131,838.18*	4,502.12	*48,461.71*
9.00E-03	*142.65*	2,454.99	*26,426.02*	12,968.30	*139,593.37*	4,766.95	*51,312.39*
9.50E-03	*150.58*	2,591.38	*27,894.14*	13,688.76	*147,348.56*	5,031.78	*54,163.08*
0.01	*158.50*	2,727.77	*29,362.25*	14,409.22	*155,103.75*	5,296.61	*57,013.77*
0.02	*237.75*	4,091.65	*44,043.37*	21,613.83	*232,655.62*	7,944.92	*85,520.66*
0.02	*317.00*	5,455.54	*58,724.50*	28,818.44	*310,207.49*	10,593.22	*114,027.54*
0.03	*396.26*	6,819.42	*73,405.62*	36,023.05	*387,759.37*	13,241.53	*142,534.43*
0.03	*475.51*	8,183.31	*88,086.74*	43,227.67	*465,311.24*	15,889.83	*171,041.31*
0.04	*554.76*	9,547.19	*102,767.87*	50,432.28	*542,863.11*	18,538.14	*199,548.20*
0.04	*634.01*	10,911.07	*117,448.99*	57,636.89	*620,414.99*	21,186.44	*228,055.08*
0.05	*713.26*	12,274.96	*132,130.11*	64,841.50	*697,966.86*	23,834.75	*256,561.97*
0.05	*792.51*	13,638.84	*146,811.24*	72,046.11	*775,518.73*	26,483.05	*285,068.86*
0.06	*871.76*	15,002.73	*161,492.36*	79,250.72	*853,070.61*	29,131.36	*313,575.74*
0.06	*951.01*	16,366.61	*176,173.49*	86,455.33	*930,622.48*	31,779.66	*342,082.63*
0.07	*1,030.26*	17,730.50	*190,854.61*	93,659.94	*1,008,174.35*	34,427.97	*370,589.51*
0.07	*1,109.51*	19,094.38	*205,535.73*	100,864.55	*1,085,726.22*	37,076.27	*399,096.40*
0.08	*1,188.77*	20,458.27	*220,216.86*	108,069.16	*1,163,278.10*	39,724.58	*427,603.28*
0.08	*1,268.02*	21,822.15	*234,897.98*	115,273.78	*1,240,829.97*	42,372.88	*456,110.17*
0.09	*1,347.27*	23,186.03	*249,579.11*	122,478.39	*1,318,381.84*	45,021.19	*484,617.06*
0.09	*1,426.52*	24,549.92	*264,260.23*	129,683.00	*1,395,933.72*	47,669.49	*513,123.94*
0.10	*1,505.77*	25,913.80	*278,941.35*	136,887.61	*1,473,485.59*	50,317.80	*541,630.83*
0.10	*1,585.02*	27,277.69	*293,622.48*	144,092.22	*1,551,037.46*	52,966.10	*570,137.71*
0.15	*2,377.53*	40,916.53	*440,433.72*	216,138.33	*2,326,556.20*	79,449.15	*855,206.57*
0.20	*3,170.04*	54,555.37	*587,244.95*	288,184.44	*3,102,074.93*	105,932.20	*1,140,275.42*
0.25	*3,962.55*	68,194.22	*734,056.19*	360,230.55	*3,877,593.66*	132,415.25	*1,425,344.28*
0.30	*4,755.06*	81,833.06	*880,867.43*	432,276.66	*4,653,112.39*	158,898.31	*1,710,413.14*
0.35	*5,547.57*	95,471.90	*1,027,678.67*	504,322.77	*5,428,631.12*	185,381.36	*1,995,481.99*
0.40	*6,340.08*	109,110.75	*1,174,489.91*	576,368.88	*6,204,149.86*	211,864.41	*2,280,550.85*
0.45	*7,132.59*	122,749.59	*1,321,301.15*	648,414.99	*6,979,668.59*	238,347.46	*2,565,619.70*
0.50	*7,925.10*	136,388.43	*1,468,112.38*	720,461.10	*7,755,187.32*	264,830.51	*2,850,688.56*

* Soil texture class and typical hydraulic conductivity values under saturated soil conditions derived from Rawls et al (1982) for all textures except silt, which is taken from Carsel & Parrish (1988).

Discharge Rate to Infiltration Area		Infiltration Area Required Based on Saturated Hydraulic Conductivity of the Following Soil Texture Classes*					
		Sandy Clay Loam		Clay Loam		Silty Clay Loam	
m^3/s	gal/min	m^2	ft^2	m^2	ft^2	m^2	ft^2
1.00E-04	1.59	83.75	901.52	156.74	1,687.18	240.38	2,587.55
2.00E-04	3.17	167.50	1,803.05	313.48	3,374.36	480.77	5,175.10
3.00E-04	4.76	251.26	2,704.57	470.22	5,061.54	721.15	7,762.64
4.00E-04	6.34	335.01	3,606.10	626.96	6,748.71	961.54	10,350.19
5.00E-04	7.93	418.76	4,507.62	783.70	8,435.89	1,201.92	12,937.74
6.00E-04	9.51	502.51	5,409.15	940.44	10,123.07	1,442.31	15,525.29
7.00E-04	11.10	586.26	6,310.67	1,097.18	11,810.25	1,682.69	18,112.84
8.00E-04	12.68	670.02	7,212.19	1,253.92	13,497.43	1,923.08	20,700.38
9.00E-04	14.27	753.77	8,113.72	1,410.66	15,184.61	2,163.46	23,287.93
1.00E-03	15.85	837.52	9,015.24	1,567.40	16,871.79	2,403.85	25,875.48
1.50E-03	23.78	1,256.28	13,522.86	2,351.10	25,307.68	3,605.77	38,813.22
2.00E-03	31.70	1,675.04	18,030.49	3,134.80	33,743.57	4,807.69	51,750.96
2.50E-03	39.63	2,093.80	22,538.11	3,918.50	42,179.47	6,009.62	64,688.70
3.00E-03	47.55	2,512.56	27,045.73	4,702.19	50,615.36	7,211.54	77,626.44
3.50E-03	55.48	2,931.32	31,553.35	5,485.89	59,051.25	8,413.46	90,564.18
4.00E-03	63.40	3,350.08	36,060.97	6,269.59	67,487.15	9,615.38	103,501.92
4.50E-03	71.33	3,768.84	40,568.59	7,053.29	75,923.04	10,817.31	116,439.66
5.00E-03	79.25	4,187.60	45,076.21	7,836.99	84,358.93	12,019.23	129,377.40
5.50E-03	87.18	4,606.37	49,583.84	8,620.69	92,794.83	13,221.15	142,315.14
6.00E-03	95.10	5,025.13	54,091.46	9,404.39	101,230.72	14,423.08	155,252.88
6.50E-03	103.03	5,443.89	58,599.08	10,188.09	109,666.61	15,625.00	168,190.63
7.00E-03	110.95	5,862.65	63,106.70	10,971.79	118,102.51	16,826.92	181,128.37
7.50E-03	118.88	6,281.41	67,614.32	11,755.49	126,538.40	18,028.85	194,066.11
8.00E-03	126.80	6,700.17	72,121.94	12,539.18	134,974.29	19,230.77	207,003.85
8.50E-03	134.73	7,118.93	76,629.56	13,322.88	143,410.19	20,432.69	219,941.59
9.00E-03	142.65	7,537.69	81,137.19	14,106.58	151,846.08	21,634.62	232,879.33
9.50E-03	150.58	7,956.45	85,644.81	14,890.28	160,281.97	22,836.54	245,817.07
0.01	158.50	8,375.21	90,152.43	15,673.98	168,717.87	24,038.46	258,754.81
0.02	237.75	12,562.81	135,228.64	23,510.97	253,076.80	36,057.69	388,132.21
0.02	317.00	16,750.42	180,304.86	31,347.96	337,435.74	48,076.92	517,509.62
0.03	396.26	20,938.02	225,381.07	39,184.95	421,794.67	60,096.15	646,887.02
0.03	475.51	25,125.63	270,457.29	47,021.94	506,153.61	72,115.38	776,264.42
0.04	554.76	29,313.23	315,533.50	54,858.93	590,512.54	84,134.62	905,641.83
0.04	634.01	33,500.84	360,609.72	62,695.92	674,871.47	96,153.85	1,035,019.23
0.05	713.26	37,688.44	405,685.93	70,532.92	759,230.41	108,173.08	1,164,396.63
0.05	792.51	41,876.05	450,762.14	78,369.91	843,589.34	120,192.31	1,293,774.04
0.06	871.76	46,063.65	495,838.36	86,206.90	927,948.28	132,211.54	1,423,151.44
0.06	951.01	50,251.26	540,914.57	94,043.89	1,012,307.21	144,230.77	1,552,528.85
0.07	1,030.26	54,438.86	585,990.79	101,880.88	1,096,666.14	156,250.00	1,681,906.25
0.07	1,109.51	58,626.47	631,067.00	109,717.87	1,181,025.08	168,269.23	1,811,283.65
0.08	1,188.77	62,814.07	676,143.22	117,554.86	1,265,384.01	180,288.46	1,940,661.06
0.08	1,268.02	67,001.68	721,219.43	125,391.85	1,349,742.95	192,307.69	2,070,038.46
0.09	1,347.27	71,189.28	766,295.64	133,228.84	1,434,101.88	204,326.92	2,199,415.87
0.09	1,426.52	75,376.88	811,371.86	141,065.83	1,518,460.82	216,346.15	2,328,793.27
0.10	1,505.77	79,564.49	856,448.07	148,902.82	1,602,819.75	228,365.38	2,458,170.67
0.10	1,585.02	83,752.09	901,524.29	156,739.81	1,687,178.68	240,384.62	2,587,548.08
0.15	2,377.53	125,628.14	1,352,286.43	235,109.72	2,530,768.03	360,576.92	3,881,322.12
0.20	3,170.04	167,504.19	1,803,048.58	313,479.62	3,374,357.37	480,769.23	5,175,096.15
0.25	3,962.55	209,380.23	2,253,810.72	391,849.53	4,217,946.71	600,961.54	6,468,870.19
0.30	4,755.06	251,256.28	2,704,572.86	470,219.44	5,061,536.05	721,153.85	7,762,644.23
0.35	5,547.57	293,132.33	3,155,335.01	548,589.34	5,905,125.39	841,346.15	9,056,418.27
0.40	6,340.08	335,008.38	3,606,097.15	626,959.25	6,748,714.73	961,538.46	10,350,192.31
0.45	7,132.59	376,884.42	4,056,859.30	705,329.15	7,592,304.08	1,081,730.77	11,643,966.35
0.50	7,925.10	418,760.47	4,507,621.44	783,699.06	8,435,893.42	1,021,923.08	12,937,740.38

* Soil texture class and typical hydraulic conductivity values under saturated soil conditions derived from Rawls et al (1982) for all textures except silt, which is taken from Carsel & Parrish (1988).

Discharge Rate to Infiltration Area		Infiltration Area Required Based on Saturated Hydraulic Conductivity of the Following Soil Texture Classes*					
		Sandy Clay		Silty Clay		Clay	
m³/s	gal/min	m²	ft²	m²	ft²	m²	ft²
1.00E-04	1.59	300.30	3,232.49	400.00	4,305.68	602.41	6,484.46
2.00E-04	3.17	600.60	6,464.98	800.00	8,611.36	1,204.82	12,968.92
3.00E-04	4.76	900.90	9,697.48	1,200.00	12,917.04	1,807.23	19,453.37
4.00E-04	6.34	1,201.20	12,929.97	1,600.00	17,222.72	2,409.64	25,937.83
5.00E-04	7.93	1,501.50	16,162.46	2,000.00	21,528.40	3,012.05	32,422.29
6.00E-04	9.51	1,801.80	19,394.95	2,400.00	25,834.08	3,614.46	38,906.75
7.00E-04	11.10	2,102.10	22,627.45	2,800.00	30,139.76	4,216.87	45,391.20
8.00E-04	12.68	2,402.40	25,859.94	3,200.00	34,445.44	4,819.28	51,875.66
9.00E-04	14.27	2,702.70	29,092.43	3,600.00	38,751.12	5,421.69	58,360.12
1.00E-03	15.85	3,003.00	32,324.92	4,000.00	43,056.80	6,024.10	64,844.58
1.50E-03	23.78	4,504.50	48,487.39	6,000.00	64,585.20	9,036.14	97,266.87
2.00E-03	31.70	6,006.01	64,649.85	8,000.00	86,113.60	12,048.19	129,689.16
2.50E-03	39.63	7,507.51	80,812.31	10,000.00	107,642.00	15,060.24	162,111.45
3.00E-03	47.55	9,009.01	96,974.77	12,000.00	129,170.40	18,072.29	194,533.73
3.50E-03	55.48	10,510.51	113,137.24	14,000.00	150,698.80	21,084.34	226,956.02
4.00E-03	63.40	12,012.01	129,299.70	16,000.00	172,227.20	24,096.39	259,378.31
4.50E-03	71.33	13,513.51	145,462.16	18,000.00	193,755.60	27,108.43	291,800.60
5.00E-03	79.25	15,015.02	161,624.62	20,000.00	215,284.00	30,120.48	324,222.89
5.50E-03	87.18	16,516.52	177,787.09	22,000.00	236,812.40	33,132.53	356,645.18
6.00E-03	95.10	18,018.02	193,949.55	24,000.00	258,340.80	36,144.58	389,067.47
6.50E-03	103.03	19,519.52	210,112.01	26,000.00	279,869.20	39,156.63	421,489.76
7.00E-03	110.95	21,021.02	226,274.47	28,000.00	301,397.60	42,168.67	453,912.05
7.50E-03	118.88	22,522.52	242,436.94	30,000.00	322,926.00	45,180.72	486,334.34
8.00E-03	126.80	24,024.02	258,599.40	32,000.00	344,454.40	48,192.77	518,756.63
8.50E-03	134.73	25,525.53	274,761.86	34,000.00	365,982.80	51,204.82	551,178.92
9.00E-03	142.65	27,027.03	290,924.32	36,000.00	387,511.20	54,216.87	583,601.20
9.50E-03	150.58	28,528.53	307,086.79	38,000.00	409,039.60	57,228.92	616,023.49
0.01	158.50	30,030.03	323,249.25	40,000.00	430,568.00	60,240.96	648,445.78
0.02	237.75	45,045.05	484,873.87	60,000.00	645,852.00	90,361.45	972,668.67
0.02	317.00	60,060.06	646,498.50	80,000.00	861,136.00	120,481.93	1,296,891.57
0.03	396.26	75,075.08	808,123.12	100,000.00	1,076,420.00	150,602.41	1,621,114.46
0.03	475.51	90,090.09	969,747.75	120,000.00	1,291,704.00	180,722.89	1,945,337.35
0.04	554.76	105,105.11	1,131,372.37	140,000.00	1,506,988.00	210,843.37	2,269,560.24
0.04	634.01	120,120.12	1,292,997.00	160,000.00	1,722,272.00	240,963.86	2,593,783.13
0.05	713.26	135,135.14	1,454,621.62	180,000.00	1,937,556.00	271,084.34	2,918,006.02
0.05	792.51	150,150.15	1,616,246.25	200,000.00	2,152,840.00	301,204.82	3,242,228.92
0.06	871.76	165,165.17	1,777,870.87	220,000.00	2,368,124.00	331,325.30	3,566,451.81
0.06	951.01	180,180.18	1,939,495.50	240,000.00	2,583,408.00	361,445.78	3,890,674.70
0.07	1,030.26	195,195.20	2,101,120.12	260,000.00	2,798,692.00	391,566.27	4,214,897.59
0.07	1,109.51	210,210.21	2,262,744.74	280,000.00	3,013,976.00	421,686.75	4,539,120.48
0.08	1,188.77	225,225.23	2,424,369.37	300,000.00	3,229,260.00	451,807.23	4,863,343.37
0.08	1,268.02	240,240.24	2,585,993.99	320,000.00	3,444,544.00	481,927.71	5,187,566.27
0.09	1,347.27	255,255.26	2,747,618.62	340,000.00	3,659,828.00	512,048.19	5,511,789.16
0.09	1,426.52	270,270.27	2,909,243.24	360,000.00	3,875,112.00	542,168.67	5,836,012.05
0.10	1,505.77	285,285.29	3,070,867.87	380,000.00	4,090,396.00	572,289.16	6,160,234.94
0.10	1,585.02	300,300.30	3,232,492.49	400,000.00	4,305,680.00	602,409.64	6,484,457.83
0.15	2,377.53	450,450.45	4,848,738.74	600,000.00	6,458,520.00	903,614.46	9,726,686.75
0.20	3,170.04	600,600.60	6,464,984.98	800,000.00	8,611,360.00	1,204,819.28	12,968,915.66
0.25	3,962.55	750,750.75	8,081,231.23	1,000,000.00	10,764,200.00	1,506,024.10	16,211,144.58
0.30	4,755.06	900,900.90	9,697,477.48	1,200,000.00	12,917,040.00	1,807,228.92	19,453,373.49
0.35	5,547.57	1,051,051.05	11,313,723.72	1,400,000.00	15,069,880.00	2,108,433.73	22,695,602.41
0.40	6,340.08	1,201,201.20	12,929,969.97	1,600,000.00	17,222,720.00	2,409,638.55	25,937,831.33
0.45	7,132.59	1,351,351.35	14,546,216.22	1,800,000.00	19,375,560.00	2,710,843.37	29,180,060.24
0.50	7,925.10	1,501,501.50	16,162,462.46	2,000,000.00	21,528,400.00	3,012,048.19	32,422,289.16

* Soil texture class and typical hydraulic conductivity values under saturated soil conditions derived from Rawls et al (1982) for all textures except silt, which is taken from Carsel & Parrish (1988).

Appendix A— Glossary

berm—a manufactured structure built above grade, typically constructed of soil and designed to contain or divert water

collection pipe—a pipe that receives runoff from the collection area in a gravity vegetated filter strip system and transfers it to the distribution channel/pipe and infiltration area

conveyance pipe—a pipe used to transfer runoff from the sump to the distribution pipe or distribution channel

Darcy-Weisbach Equation—an equation that can be used to calculate friction losses in a piping system

design-storm event—the storm event, e.g., 25-year/24-hour storm, that the design is carried out for

discharge—to emit or release a material (water, washwater, runoff, etc.)

distribution pipe—a pipe that evenly distributes flow from the runoff collection basin across the full width of the infiltration area

dosing—an action whereby runoff is periodically purged through the system by hydraulic or mechanical means to prevent solids buildup in the collection area or sump

effluent—a material, e.g., runoff, that is flowing outward

endophytes—certain parasitic fungi or algae

energy dissipation—a mechanism to break up the energy of a flowing liquid

evapotranspiration—the total water loss from the soil including that by direct evaporation and that by transpiration from the surface of plants

forages—whole plants used to feed livestock; usually comprise a mixture of different species

ground water—water that resides within pores, fractures or other kinds of open spaces within solid geologic materials

Guelph Permeameter or **Cylinder Infiltrometer**—an instrument used to measure *in-situ* hydraulic properties e.g., saturated hydraulic conductivity of the soil

head—a measure of water pressure, expressed in metres of water or kilopascals (kPa)

head differential—the elevation difference (metres) between the pump or gravity inlet elevation and the discharge elevation

heat tracing—the protection of a water pipe against freezing by installing heat cable around or along the pipe

infiltration area or **vegetated filter strip**—a densely vegetated (planted) strip of land, engineered and constructed to accept and manage runoff through settling, filtration, absorption and infiltration processes

influent—a material, e.g., runoff, that is flowing inward

integrated storage facility—a type of facility where runoff is stored directly within the outdoor livestock yard/confinement area or permanent manure storage area; it has a sufficiently high containment wall around all or a portion of the area, serving to retain the required storage volume

liquid loading capacity—the maximum allowable hydraulic loading amount that an infiltration area can accept over a specified period of time, e.g., week

Manning's Equation—an equation used to determine the capacity of a pipe for gravity and pressure flows

maximum head—a measure of the maximum water pressure expressed in metres of water or kilopascals (kPa)

minimum head—a measure of the minimum water pressure expressed in metres of water or kilopascals (kPa)

Nutrient Management records—actual events and details that a person documents and keeps pertaining to practices carried out under nutrient management

orifice plate—a flow-restrictive/measurement device consisting of an opening with a closed perimeter that is designed to allow a fixed rate of runoff to flow through

pathogens—disease-causing microorganisms in manure that can travel with runoff to contaminate surface water and ground water

permanent solid nutrient storage facility—a permanent nutrient storage facility that is designed and constructed to contain solid prescribed material

prescribed material—an agricultural source material or a non-agricultural source material

return period (e.g., 25-year return period)—the average period of time within which the depth or intensity of rainfall for a given duration, e.g., 5-minute, 24-hour, etc. will be equaled or exceeded once

rills—small channels formed in the land surface, as a result of water erosion, that can be graded out with conventional tillage equipment

runoff—a liquid, usually generated by rainfall or snow, that has come into contact with manure and may contain components of manure in solution and is no longer contained in a storage facility

saturated hydraulic conductivity—measure of the rate at which water infiltrates the soil under saturated conditions

screens—devices that retain particles and debris contained in runoff for the purpose of minimizing the potential for clogging of the downstream system components of the vegetated filter strip

sheet flow—the movement of liquid, e.g., runoff, over the land surface in a thin layer

soil horizon—a layer of soil approximately parallel to the land surface and identified by its physical characteristics

solids—materials filled with matter that tend to keep their form rather than flow like a liquid

splash pad—an erosion-resistant material, e.g., concrete slabs or gravel pad, placed to protect the soil in the infiltration area beneath the orifice opening in the distribution pipe and to assist in maintaining sheet flow over the vegetated filter strip

storage/settling basin—stores runoff and facilitates solid settling, and can be either an integrated or external storage

sump—a collection basin that receives runoff from the storage/settling basin via the drainpipe, and is large enough to accommodate a siphon or pump and permits easy access for maintenance purposes

surface water

(a) a natural or artificial channel that carries water continuously throughout the year, or intermittently, and does not have established vegetation within the bed of the channel except vegetation dominated by plant communities that require or prefer the continuous presence of water or continuously saturated soil for their survival,

(b) a lake, reservoir, pond or sinkhole, or

(c) a wetland, such as a swamp, marsh, bog or fen, but not land that is being used for agricultural purposes that no longer exhibits wetland characteristics, if the wetland,

  (i) is seasonally or permanently covered by shallow water or has the water close to the surface of the ground, and

  (ii) has hydric soils and vegetation dominated by hydrophytic or water-tolerant plants

The following are not surface water:

- grassed waterways
- temporary channels for surface drainage, such as furrows or shallow channels that can be tilled and driven through
- rock chutes and spillways
- roadside ditches that do not contain a continuous or intermittent stream
- temporarily ponded areas that are normally farmed
- artificial bodies of water intended for the storage, treatment or recirculation of runoff from farm-animal yards, manure storage facilities and sites, and outdoor confinement areas

transpiration—the process of giving off of moisture through the surface of the leaves and other parts of the plants

zero-discharge system—a system that results in no discharge of the runoff from the defined infiltration area boundary

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